Cleanroom Energy Benchmarking and Efficiency Technology Transfer Assistance Site Report

Facility K

Southern California

August 2004

Sponsored By:

Lawrence Berkeley National Laboratory

Prepared By:
Rumsey Engineers, Inc
99 Linden Street
Oakland, CA 94607
www.RumseyEngineers.com

Acknowledgements

Special thanks to the entire team for their generous assistance and cooperation throughout the benchmarking process.

Project Team

Lawrence Berkeley National Laboratory	Rumsey Engineers, Inc
Bill Tschudi	Peter Rumsey
Dale Sartor	Achai Broner
	Larry Chu
	John Weale

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I. INTRODUCTION

As part of the California Energy Commission PIER study, energy use at Facility K was monitored June 21 to June 25, 2004. The project is administered by LBNL (Lawrence Berkeley National Laboratory) and funded through the California Energy Commission. Facility K is a building that houses primarily laboratory spaces, office spaces, common areas, and support areas.

This site report reviews the data collected by the monitoring team and presents a set of performance metrics as well as a complete set of trended data points for the end uses of energy for equipment supporting and located in cleanrooms or laboratories. The chilled water plant at this facility was not measured in detail since several chilled water plants have been benchmarked as part of this study at prior sites. Energy metrics were established that allow cleanroom and laboratory owners to evaluate their energy efficiency performance and identify opportunities for improvements that reduce their overall operating costs.

With this report, Facility K is receiving the energy monitoring data collected along with a few energy efficiency improvement observations. This Site Report summarizes the data collected and presents energy performance metrics with which will allow the facility to compare selected systems' performance to others. A database of other lab energy performance can be found at the Laboratories for the 21st Century website (http://www.dc.lbl.gov/Labs21/Labs21intro.php).

First, this report reviews the site characteristics, noting design features of the mechanical plant and the cleanrooms or laboratories monitored. Second, the energy use for the cleanrooms or laboratories and major mechanical equipment is broken down into major components. Third, performance metrics recorded through the project are presented. Finally, key energy efficiency observations for the facility will be noted. The data collected, trended graphs and methodology documentation are included among the appendices.

II. REVIEW OF SITE CHARACTERISTICS

A. Site

Facility K, located in Southern California, is a 113,000 square foot, three-story building that is approximately five years old. The building houses primarily laboratory spaces, office spaces, and common areas, such as hallways and restrooms. The 1st and 2nd floors have a nearly identical layout; the building has two wings, with one referred to as the "North Wing" and the other as the "East Wing". Each wing has both a Chemistry and Biology Laboratory. The basement consists of additional laboratory and common areas.

This site has on-site power production created by a natural gas cogeneration system. The waste heat from this system is recovered and utilized for an absorption chiller and heating hot water. A 1,875 kVA/1,500 kW diesel generator provides backup power in the case of a utility failure. A 100 kVA uninterruptible power supply (UPS) system is also utilized to provide backup power to the computer servers.

Absorption Chiller

The environmental systems serving the laboratories run 8,760 hours a year in order to maintain conditions and provide a safe lab environment. The 1^{st} and 2^{nd} floor laboratory and office spaces are conditioned by two large air handlers served by a chilled water plant, and a hot water boiler plant. The air handling systems serving these areas are both VAV (variable air volume) systems providing once-through, 100% outside air. Exhaust is provided to these areas also. The basement laboratory spaces are conditioned also by an air handler providing once-through, 100% outside air. This air handler is also served by the chilled water plant, and the hot water boiler plant mentioned above.
The common areas on all three floors are served by three traditional air handlers, which provide both make up and recirculation air. The common areas are made up of the hallways, lobby, restrooms, and some office areas. These air handlers are also served with chilled and hot water from the plants mentioned above. The air handlers serving these spaces are AH-3, AH-4, AH-6 and AH-7.

The spaces chosen for monitoring are the Chemistry and Biology Laboratories located on the 1^{st} and 2^{nd} floors. The air handler that serves the Chemistry and Biology Laboratories in the "North Wing" is AH-1/2 rated for a nominal air delivery of 111,500 cfm (cubic feet per minute). An exhaust system, consisting of six identical fans connected to a common plenum serves the "North Wing". The air handler that serves the Chemistry and Biology Laboratories in the "East Wing" is AH-5/6 rated for a nominal air delivery of 101,000 cfm. Exhaust is provided to the "East Wing" by four exhaust fans connected to a common plenum.

The chilled water plant consists of: two 600 ton, variable speed driven centrifugal chillers; two induced-draft cooling towers; three primary and two secondary pumps. The system utilizes a constant flow primary-variable flow secondary pumping system. Currently there is a new building under construction, which shares its chilled water plant with this building. The absorption chiller, which is part of the new building, is being used for the existing building to take advantage of the waste heat being generated by the cogeneration system.

B. "North Wing" Chemistry and Biology Laboratories

Air Handler AH-1/2

The "North Wing" laboratories account for 33,100 sf or 29% of the total building area. The Chemistry Labs are 12,450 sf and the Biology Labs are 20,650 sf. The lab is made up of actual lab areas where the experiments are conducted and office areas adjacent to the labs; this is what defines the laboratories. There is no physical wall of separation between the labs and the office areas. The air is delivered to the office areas spaces via a ducted VAV system, and cascaded to the lab areas. The labs operate 24 hours a day, although they are not continually occupied. The Chemistry Laboratories consist of primarily ten modules (five on each floor). The modules are very similar to one another in that they are approximately the same square footage and contain similar equipment. Each module contains four bench mounted fume hoods, which have occupancy sensors and sash position sensors. These sensors work in conjunction with the VAV dampers to minimize the amount of air exhausted and supplied to the areas to save fan, cooling, and heating energy. The Biology

Laboratories are made up of primarily eight modules (four on each floor). The modules are very similar in square footage and equipment.

The “North Wing” is served by one make up air handler (AH-1/2) with a nominal air delivery rate of 111,500 cfm. The make up air unit delivers air into the laboratories and office spaces via ceiling diffusers. The air handler consists of two sections; each section consists of a variable speed driven fan, cooling coil and hot water coil. The two sections are joined by a common supply plenum.

C. “East Wing” Chemistry and Biology Laboratories

The “East Wing” laboratories account for 23,000 sf or 20% of the total building area. The Chemistry Labs are 9,400 sf and the Biology Labs are 13,600 sf. The laboratories also are made up of office spaces similar to the “North Wing” Laboratories. The air is delivered to the office areas spaces via a ducted VAV system, and cascaded to the lab areas. The labs operate 24 hours a day, although they are not continually occupied. The Chemistry Laboratories consists of primarily eight modules (four on each floor). The modules are very similar to one another as described above. Each module contains four bench mounted fume hoods, which have occupancy sensors and sash position sensors similar to the “North Wing” Labs mentioned above. The Biology Laboratories are made up of primarily eight modules (four on each floor). The modules are very similar in square footage and equipment.

Air Handler AH-5/6

The “East Wing” is served by one make up air handler (AH-5/6) rated for a nominal air delivery rate of 101,000 cfm. The make up air unit delivers air into the laboratories and office areas via ceiling diffusers. The air handler consists of two sections, similar to AH-1/2, which are joined by a common supply plenum.

III. SITE ENERGY USE CHARACTERISTICS

A. Laboratory Power Consumption

The power consumption attributed to the laboratory air handling systems, exhaust fans, process tools, and lighting are reported in Tables 1, 2 and 3. These values were directly measured. Note that the cooling and heating energy are not included in the tables and chart. This breakdown of energy use by equipment helps identify the major loads. Table 1 is also shown graphically in the chart below.

Table 1. Total Laboratory Power Consumption [1]

Description	Average Load (kW)
AIR HANDLING	
Make Up Air Fans	88.7
Exhaust Fans	195.6
PROCESS POWER	
Laboratory Areas	137.2
Laboratory Office Areas	62.9
LIGHTS	70.0
TOTAL [1]	**554.4**

1. The total power consumption does not include the power and gas consumption of the chillers and boilers cooling and heating energy produced.

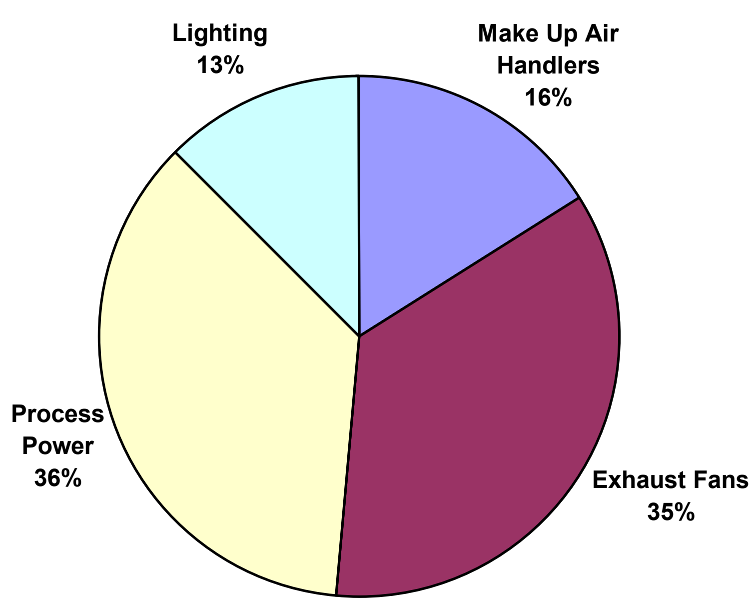


Figure 1. Total Laboratory Power Consumption

Table 2. "North Wing" Chemistry and Biology Labs Power Consumption Breakdown

Description	Average Load (kW)	Metric
AIR HANDLING		
Make Up Air Fans	46.5	0.66 W/cfm
Exhaust Fans	112.3	[3]
PROCESS POWER [1]	-	-
LIGHTS [2]		
Chemistry Labs + Offices	7.7	0.62 W/sf
Biology Labs + Offices	34.1	1.7 W/sf

1. *Process power was not determined for the individual wing.*
2. *Lighting power calculated based on lighting power density of a representative laboratory module*
3. *The metric was not calculated since an operating airflow was not determined.*

Table 3. "East Wing" Chemistry and Biology Labs Power Consumption Breakdown

Description	Average Load (kW)	Metric
AIR HANDLING		
Make Up Air Fans	42.2	0.60 W/cfm
Exhaust Fans	83.3	[3]
PROCESS POWER [1]	-	-
LIGHTS [2]		
Chemistry Labs + Offices	5.8	0.62 W/sf
Biology Labs + Offices	22.5	1.7 W/sf

1. *Process power was not determined for the individual wing.*
2. *Lighting power calculated based on lighting power density of a representative laboratory module*
3. *The metric was not calculated since an operating airflow was not determined.*

B. Electrical System Power Consumption

The table below shows the power consumption of the emergency generator standby power loss. The 1,500 kW emergency generator constantly draws power to maintain the batteries and a specific temperature of the diesel engines that drive the generator.

Table 4. Electrical System Power Consumption

Description	Average Load
ELECTRICAL SYSTEM	
Emergency Generator Standby Power	2.3 kW

IV. SYSTEM PERFORMANCE METRICS

Metrics are ratios of important performance parameters that can characterize the effectiveness of a system or component. In order to gage the efficiency of the entire building system design and operation, this project tracks key metrics at different system levels. These metrics can be used to compare designs or determine areas with the most potential for improvement via retrofit or replacement. The data used for comparison was obtained from the Laboratories for the 21st Century website (http://www.dc.lbl.gov/Labs21/Labs21intro.php).

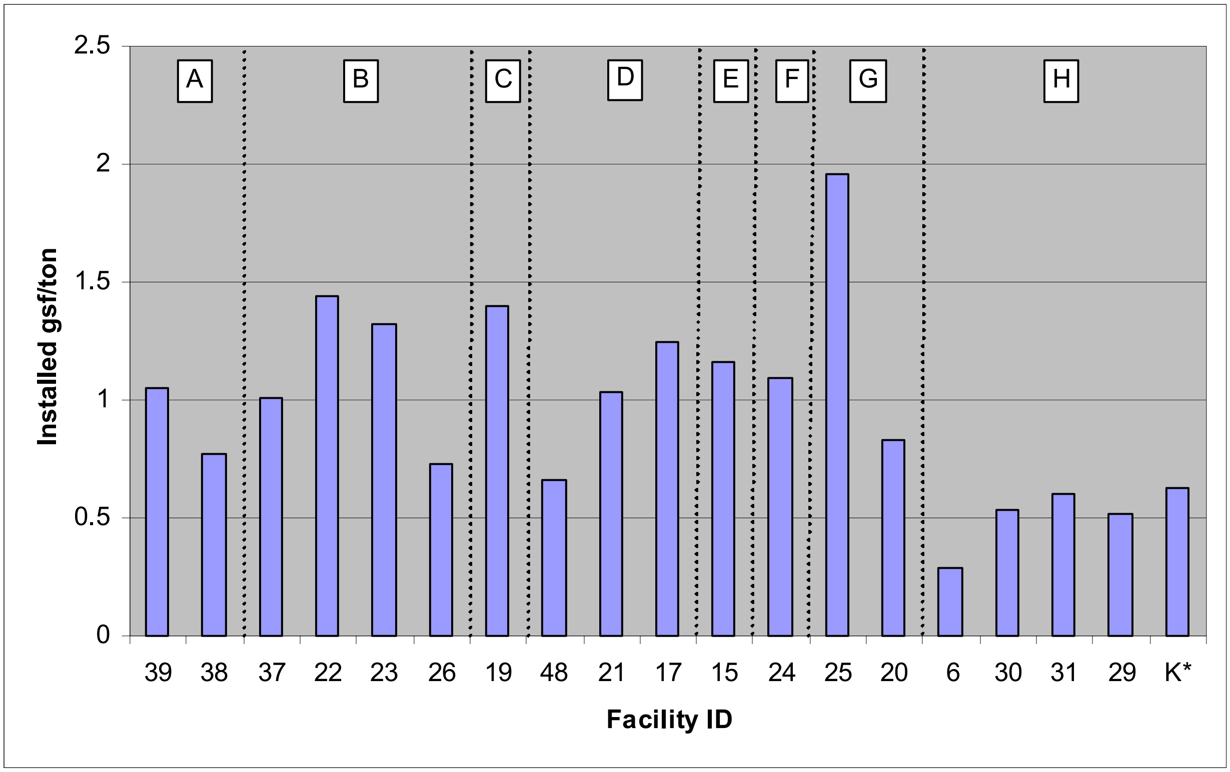
Table 5. Laboratory Metrics

Description	*"North Wing" Laboratories*	*"East Wing" Laboratories*	*Total for All Laboratories*
VENTILATION			
cfm	70,060	70,700	140,760
Fan kW	46.5	42.2	88.7
W/cfm (measured)	0.66	0.60	0.63
cfm/sf-lab (measured)	2.1	3.1	2.5
LIGHTING [1]			
W/sf-lab (measured)	1.1	1.1	1.1
PROCESS [1]			
W/sf-lab (measured)	10.9	10.9	10.9

1. Power densities calculated based on power measurements of a representative laboratory module.

The figures on the following pages compare the facility's airflow with other facilities documented in the Labs for the 21st Century online database. The facilities used for comparison are located in different parts of the nation, which essentially are representative of various climate zones (i.e. cool-humid, cold-dry, cold-humid, warm-marine, hot-humid, etc.). Note that the data shown for this facility was actually based on a spot measurement, which closely represents an average value rather than a peak value. The ventilation supply cfm/sf for Facility K is higher than a few of the compared facilities. There are a number of facilities that are actually being maintained at lower flow rates, thus a reduction in airflow to the lab spaces at this facility should be considered for energy savings (see "Site Observations Regarding Energy Efficiency" section).

Figure 2. Laboratory Ventilation Peak W/cfm

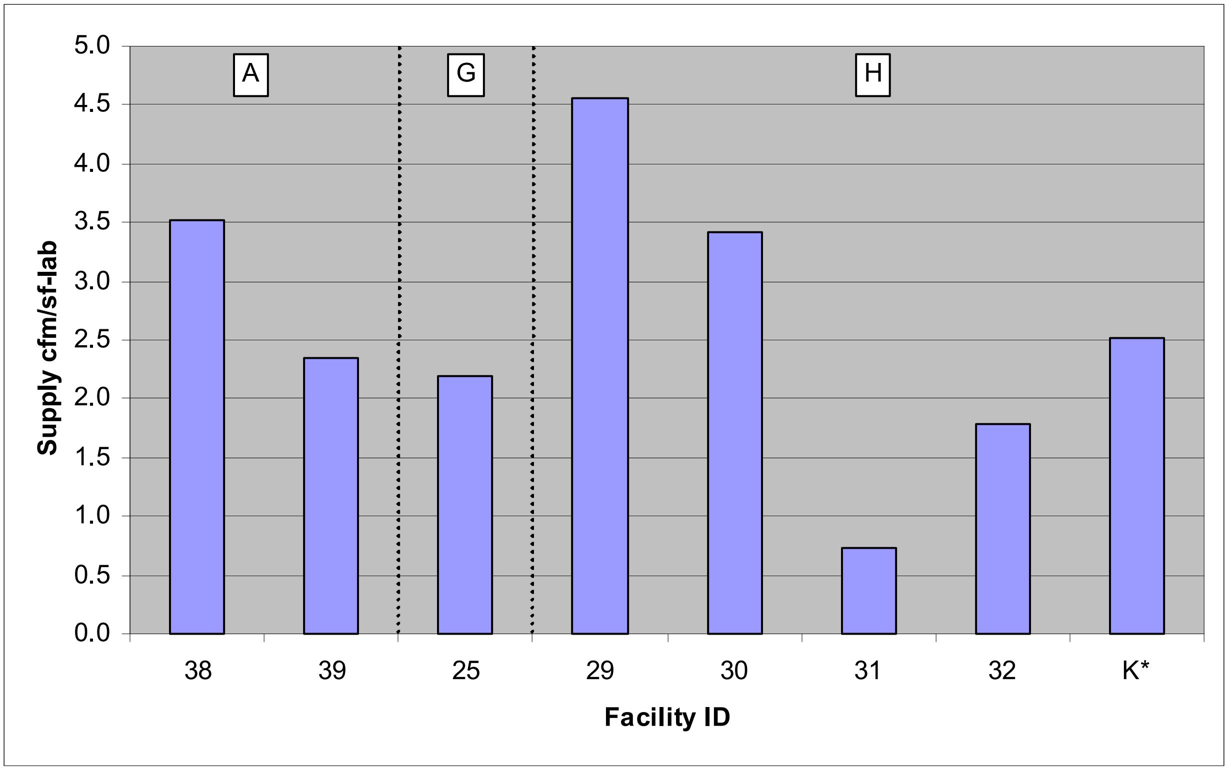


** Data for Facility K was based on a spot measurement, which closely represents an average value rather than a peak value.*

Figure 2 Legend – Climate Type, Representative City

A Cool-Dry (Boise, ID)	**E** Mixed-Marine (Salem, OR)
B Cool-Humid (Chicago, IL)	**F** Warm-Dry (El Paso, TX)
C Mixed-Dry (Albuquerque, NM)	**G** Warm-Humid (Memphis, TN)
D Mixed-Humid (Baltimore, MD)	**H** Warm-Marine (San Francisco, CA)

Figure 3. Laboratory Ventilation Peak Supply cfm/sf



* *Data for Facility K was based on a spot measurement, which closely represents an average value rather than a peak value.*

Figure 3 Legend – Climate Type, Representative City	
A Cool-Dry (Boise, ID)	**H** Warm-Marine (San Francisco, CA)
G Warm-Humid (Memphis, TN)	

Table 6. Facility Metrics

Description	***Metric***
COOLING	
gsf/ton (installed) [1]	58.8
W/gsf (installed)	9.7

1. gsf – gross square feet

The figure below shows the facility's installed cooling capacity based on the total facility area (gsf/ton). This chart is used to compare the installed cooling capacity of this facility to other laboratory facilities.

Figure 4. Installed Cooling – Gross Square Feet per Ton

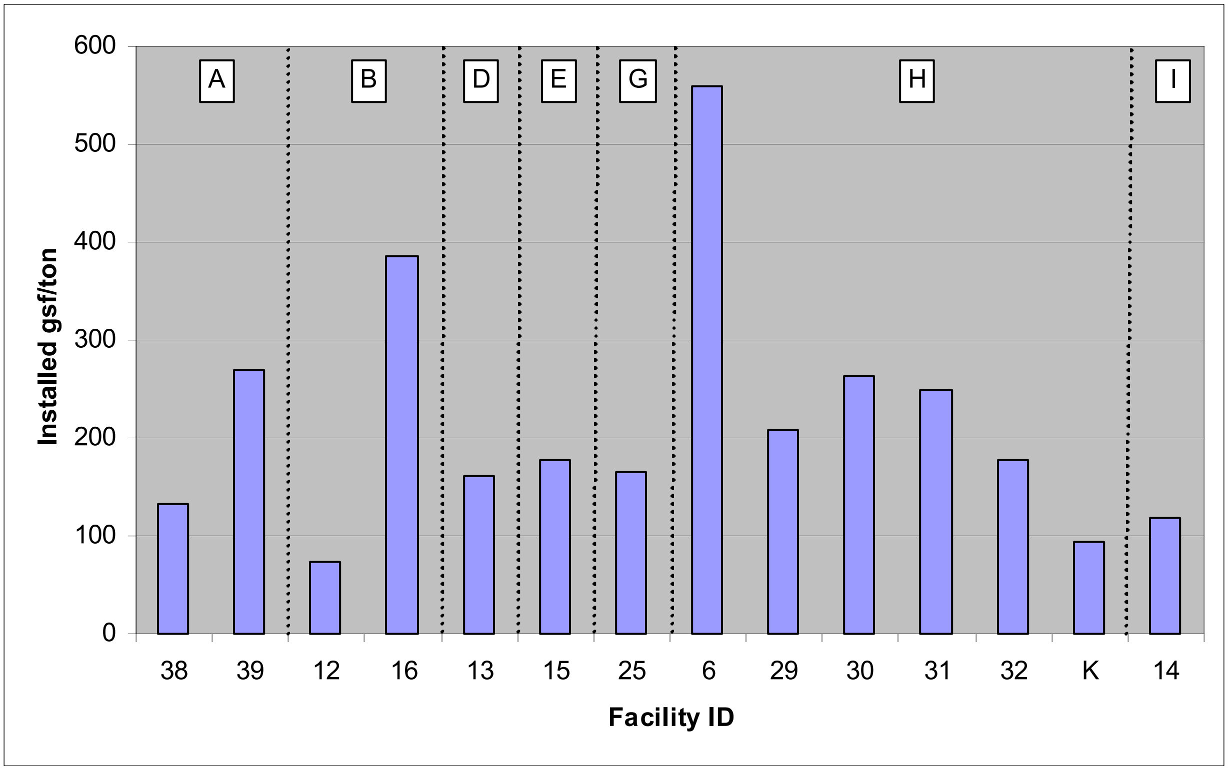


Figure 4 Legend – Climate Type, Representative City

A Cool-Dry (Boise, ID)
B Cool-Humid (Chicago, IL)
D Mixed-Humid (Baltimore, MD)
E Mixed-Marine (Salem, OR)
G Warm-Humid (Memphis, TN)
H Warm-Marine (San Francisco, CA)
I Cold-Humid (Burlington, VT)

VI. SITE OBSERVATIONS REGARDING ENERGY EFFICIENCY

Many notable energy efficiency features have already been implemented into the systems at this facility. Some of the key features are:

- Cogeneration / on-site power production
- Recovery of waste heat from cogeneration system utilized for absorption chiller and reheat in the new building
- The chilled water loop in the new building is coupled to the chilled water loop in this building, allowing the use of the absorption chiller and the cogeneration system's waste heat, and also allowing a chiller to run at higher loads. The overall chilled water plant efficiency is improved since chillers running at low partial loads are inherently inefficient.
- Cooling towers operating in parallel
- Variable air volume supply and exhaust air flow in laboratories based on fume hood sash position
- Protocol for closing fume hoods to minimum position during unoccupied hours
- Low pressure drop pre-filters on make up air handlers
- Parallel operation of make up air handler fans

- Variable speed driven centrifugal chillers
- Manifolded exhaust fans staged on and off based on maintaining a plenum pressure setpoint
- Lighting controlled via occupancy sensors
- The air handlers in the new building were sized based on measurements made in this building. The make up air handlers for the original building were sized for an 80% diversity factor versus 60% diversity for the new building.

However, there are a few additional opportunities that can be implemented to improve the overall energy efficiency at this site.

Chilled Water Temperature Reset

Chiller performance can be improved by implementing a chilled water temperature reset. When dehumidification is *not* required, there is typically a significant surplus of coil capacity. The 41 to 42°F low temperature loop could be reset to a higher temperature. Low temperature chilled water is inherently more energy intensive to produce due to the larger temperature delta, or 'lift,' the compressor is required to move heat through. On centrifugal compressors based chillers, an increase of one degree in the chilled water supply temperature improves the efficiency of the chiller by 1 to 2%. The chiller manufacturer should be consulted before radical modification of the supply temperature, but a change of a few degrees should allow for an improvement in efficiency without risk.

There are a number of chilled water resets that have been shown to work. The simplest is to set the CHW temperature based on the outside air temperature, with the lowest temperature chilled water setpoint achieved during the highest outside air temperatures and during dehumidification. A more sophisticated approach is to poll all the chilled water valves on the loop for their position. If no valve is at 90% or more open, then maximum cooling is not required and the chilled water temperature can be increased. When a valve position exceeds 90%, it indicates a space is calling for additional cooling and the chilled water temperature can be reset down. The savings from a chilled water reset are maximized when the periods of dehumidification are minimized.

Make Up Air Handler Supply Air Temperature Reset

Another strategy to save energy is to implement a supply air temperature reset on the make up air. Typically the supply air temperature delivered by the air handlers is based on the lowest room temperature or lowest average temperature (of a group of rooms) that is required. A study should be done to determine the actual requirements in each of the spaces. Additionally, reheat energy will be saved if the supply air temperature of the air handler is raised. By implementing this measure along with a chilled water temperature reset and differential pressure setpoint reset, additional energy savings will be realized.

Condenser Water Temperature Reset

The centrifugal chillers may also benefit from a reduction in lift. A reduction in the condenser water temperature of a couple degrees will achieve meaningful energy savings, however chiller stability can be compromised if it is taken too low, hence the need to verify with the chiller manufacturer before modifying this point. A bypass and a dedicated recirculation pump on the condenser water loop feeding the absorption chiller should be installed so that the warmer condenser water temperature required by the chiller can be maintained.

Add Additional Plates to the Cogeneration System Heat Exchangers (HX-9 & HX-10)

The plate and frame heat exchangers for transferring the heat generated by the cogeneration system to the cooling tower will result in pumping energy savings if more plates are added to lower the pressure drop through the device. Additionally, adding more plates will increase the heat transfer effectiveness and may result in lower flow rates for both the condenser water and engine water loops.

Chilled Water Differential Pressure Setpoint Reset

The secondary pumps on the chilled water supply loop are controlled via VFDs and a set pressure differential setpoint. An actively controlled differential setpoint can be utilized to save pumping energy. The differential setpoint can be reset based on the cooling valve positions. When the valves are partially closed, the differential setpoint can be reduced since lower water flow is required for each coil, hence the lower pressure drop required through the loop. As the valves begin to open, the differential setpoint should be increased so that adequate flow is supplied to the coils. Typically the most energy savings are realized when the coils are oversized.

Air Change Rate Nighttime Setback

Energy savings are currently achieved in the Laboratories by lowering the air change rates based on the fume hood sash positions. Setback of the airflow for the Biology Labs during unoccupied hours should be investigated to further increase energy savings. During occupied hours, the Biology Labs operate at approximately 29 ACH (air changes per hour). OSHA recommends 4 to 12 ACH for normally adequate laboratory ventilation (*source: OSHA 29 Code of Federal Regulations*). The National Institutes of Health recommends a minimum of 6 ACH. A case study at the Fred Hutchinson Cancer Research Center in Seattle has shown that a reduction in its minimum air change rate from 10 ACH to 6 ACH (occupied) and 4 ACH (unoccupied) to be successful. By reducing the air change rate during unoccupied hours from 10 to 12 ACH, significant energy savings can be achieved while safety is maintained.

Emergency Generator Standby Power Loss Reduction

The 1,500 kW emergency generator constantly draws power to maintain the batteries and a specific temperature of the diesel engines that drive the generator. An average of 2.3 kW is being consumed to prime the generator for a power outage. Claims have been made that the engine(s) of a generator can be maintained at lower temperatures without introducing any physical damage when started. The manufacturer of the generator should be contacted to explore energy reduction options.

LBNL's Low-Flow Fume Hood

LBNL has developed a low-flow fume hood, which significantly requires a lower amount of airflow as compared to a standard fume hood. Although, the airflow through the low-flow fume hood is lower than normal, a safe working environment protecting the health of the users is still maintained. Lower airflow rates translate into lower fan energy, and lower cooling and heating energy requirements.

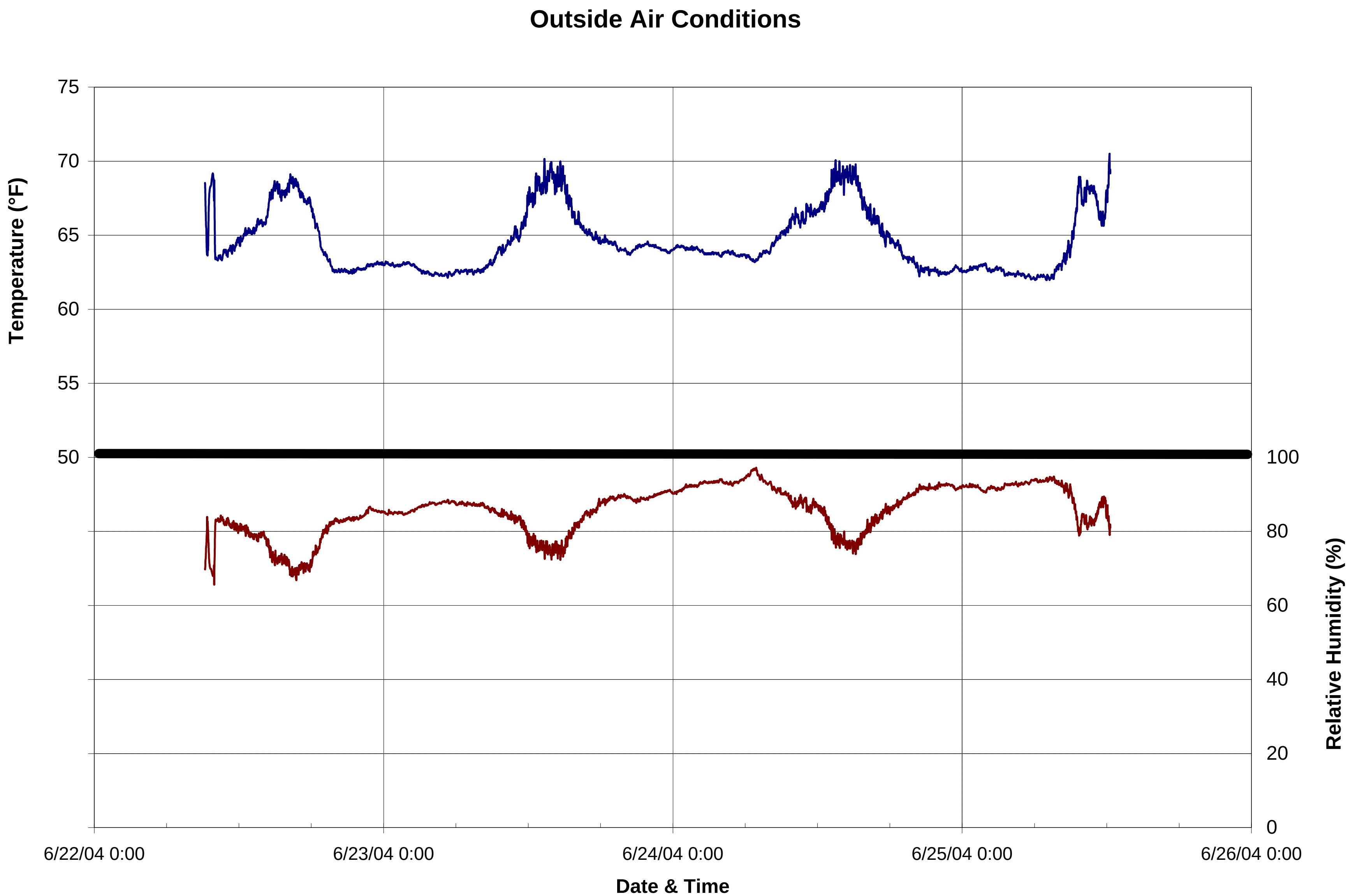
Place Refrigerators and Freezers in Separate Rooms

Refrigerators and freezers give off a substantial amount of heat to the surrounding spaces in which they are located. By placing refrigerators and freezers in a separate room, then the cooling requirements for the space may be reduced. In addition, by grouping refrigerators into a common room, the temperature requirements for that room can be relaxed (i.e. increase the room temperature setpoint) for energy savings depending on what is tolerable to the users.

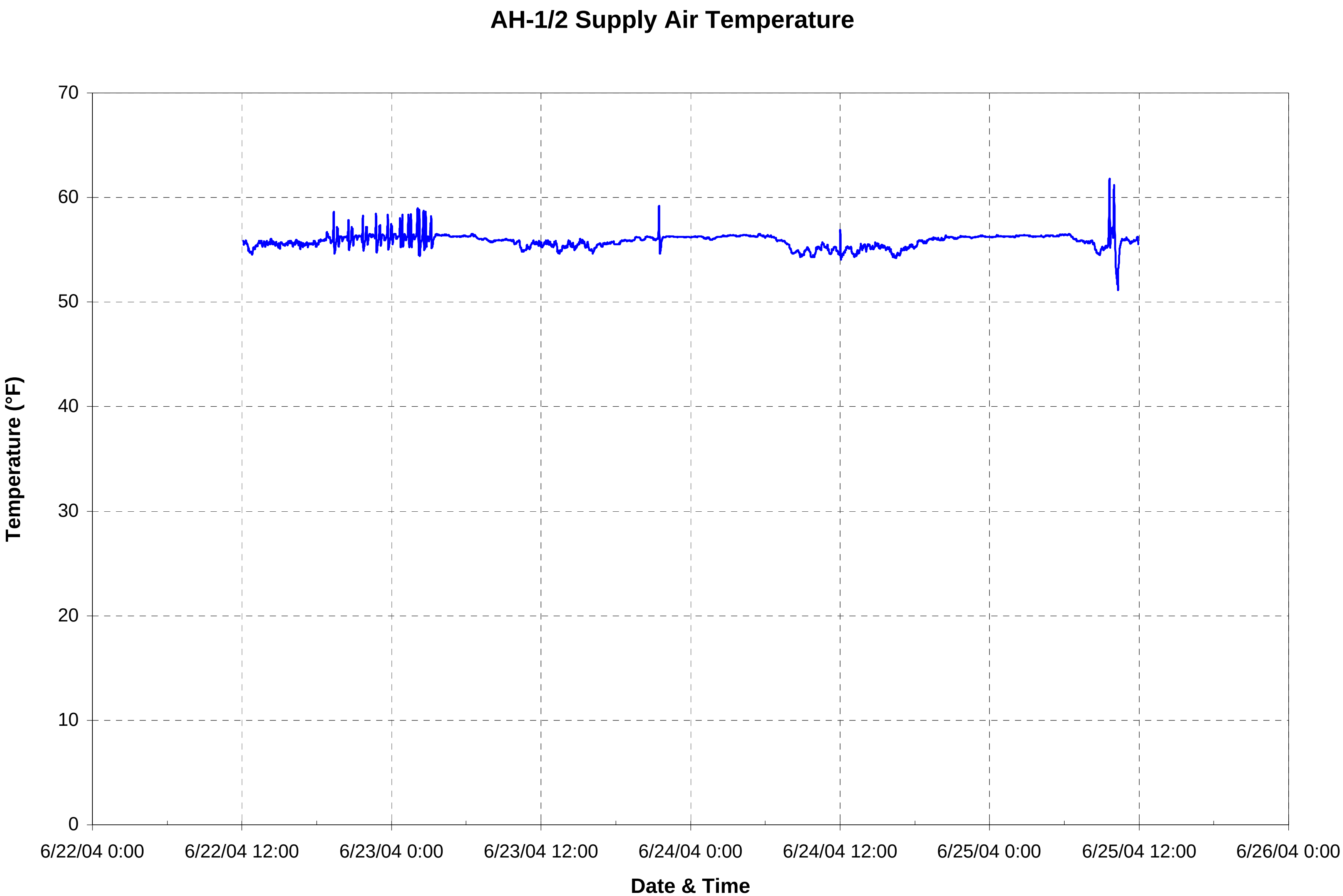
Appendix A

Trended Data Graphs

Outside Air Conditions


Outside Air Conditions
Temperature (°F)
75
70
65
60
55
50
Relative Humidity (%)
100
80
60
40
20
0
6/22/04 0:00
6/23/04 0:00
6/24/04 0:00
6/25/04 0:00
6/26/04 0:00
Date & Time

“North Wing” Chemistry & Biology Laboratories


AH-1/2 Supply Air Temperature
Temperature (°F)
70
60
50
40
30
20
10
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
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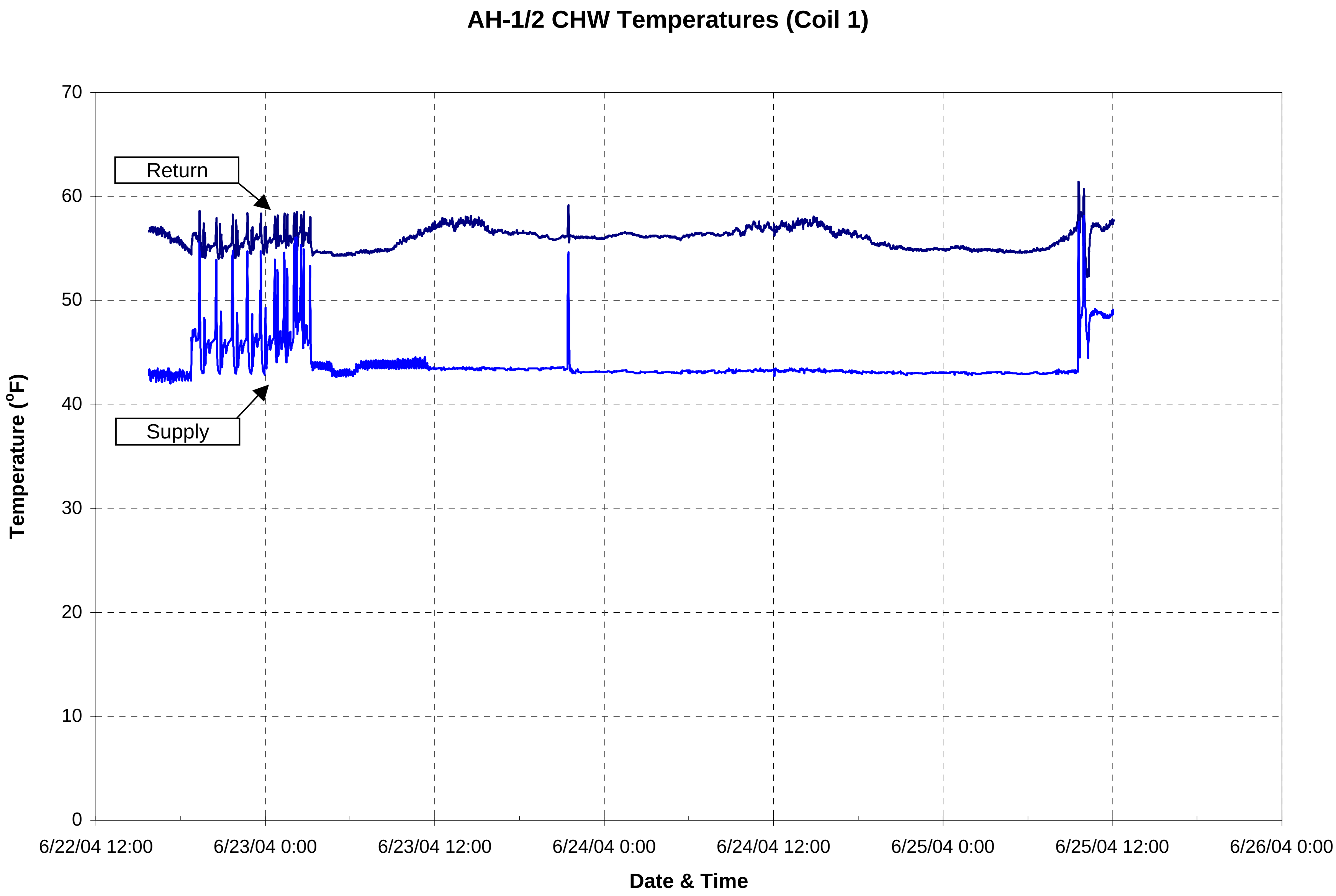
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time


AH-1/2 CHW Temperatures (Coil 1)
Return
Supply
Temperature (oF)
70
60
50
40
30
20
10
0
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
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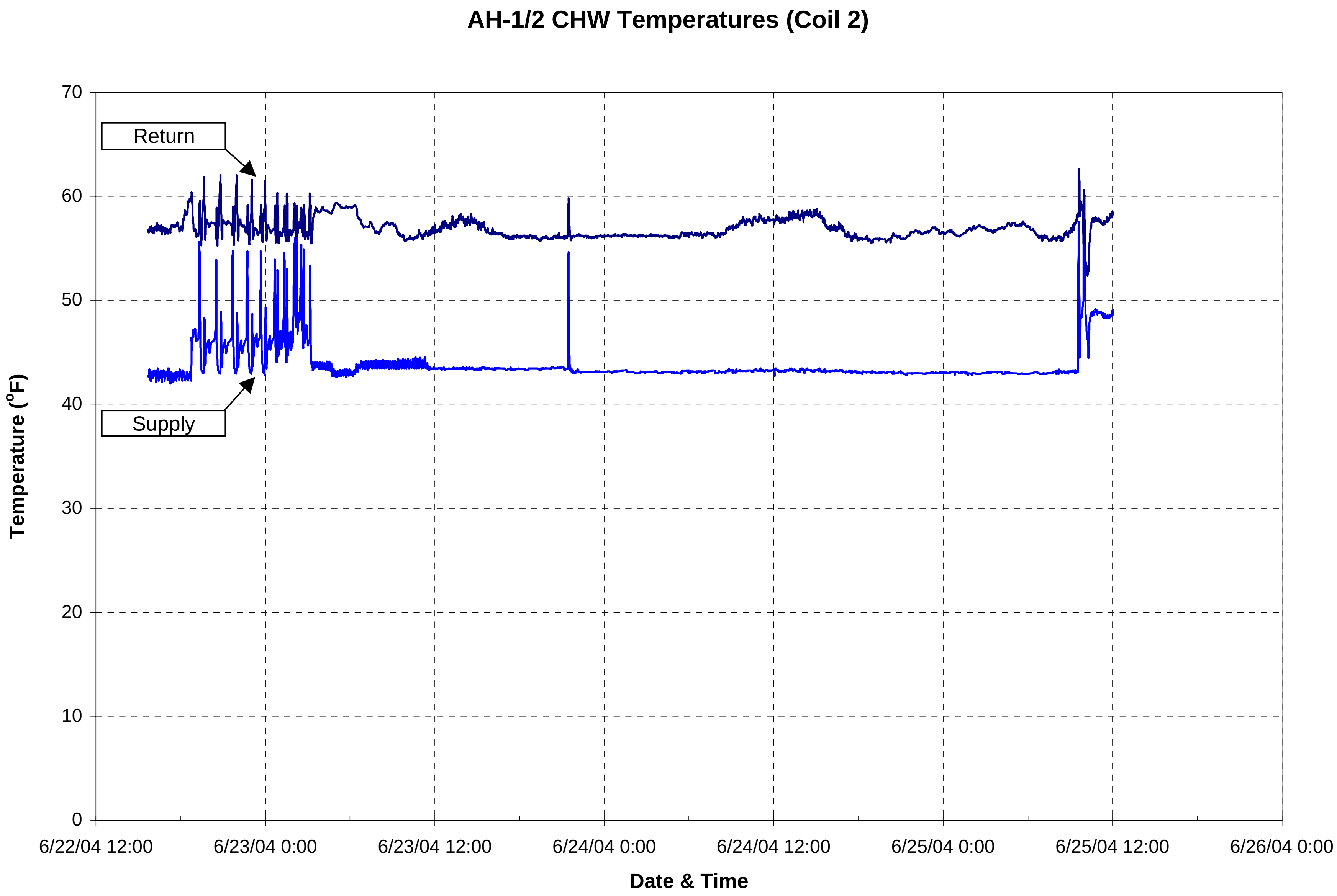
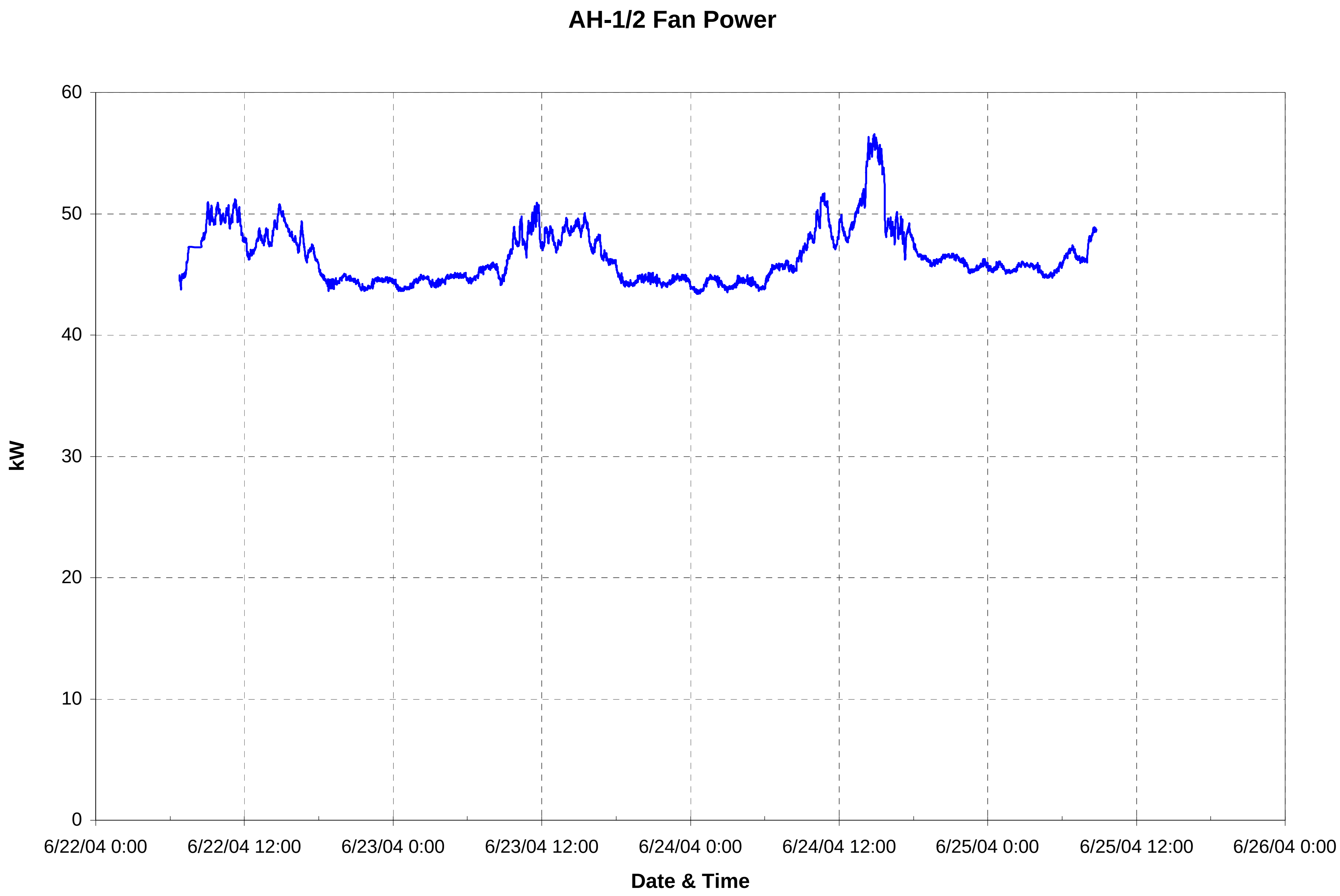
6/26/04 0:00
Date & Time


AH-1/2 CHW Temperatures (Coil 2)
Return
Supply
Temperature (^oF)
70
60
50
40
30
20
10
0
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time


AH-1/2 Fan Power
kW
60
50
40
30
20
10
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
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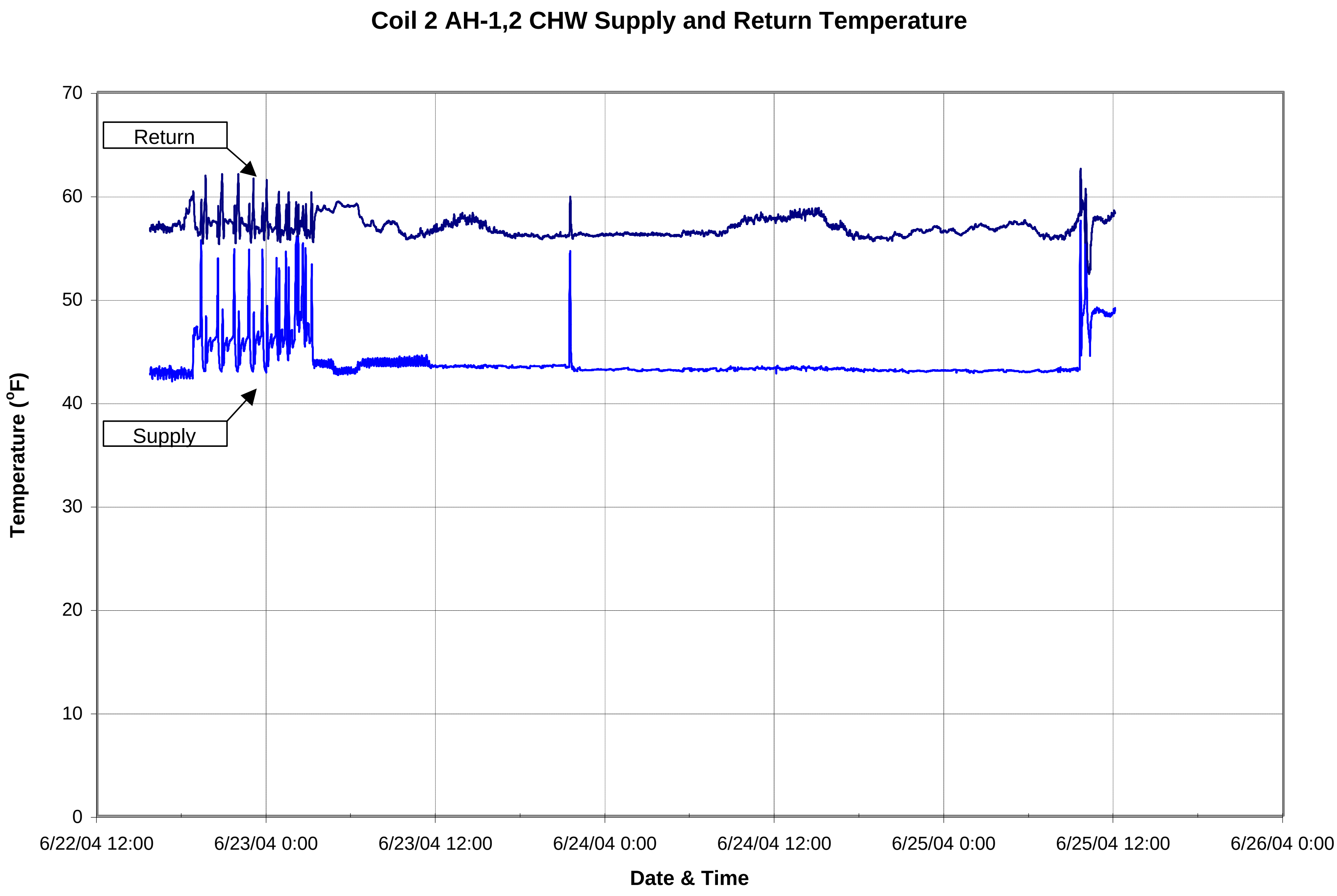
6/26/04 0:00
Date & Time


Coil 2 AH-1,2 CHW Supply and Return Temperature
Temperature (°F)
70
60
50
40
30
20
10
0
Return
Supply
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
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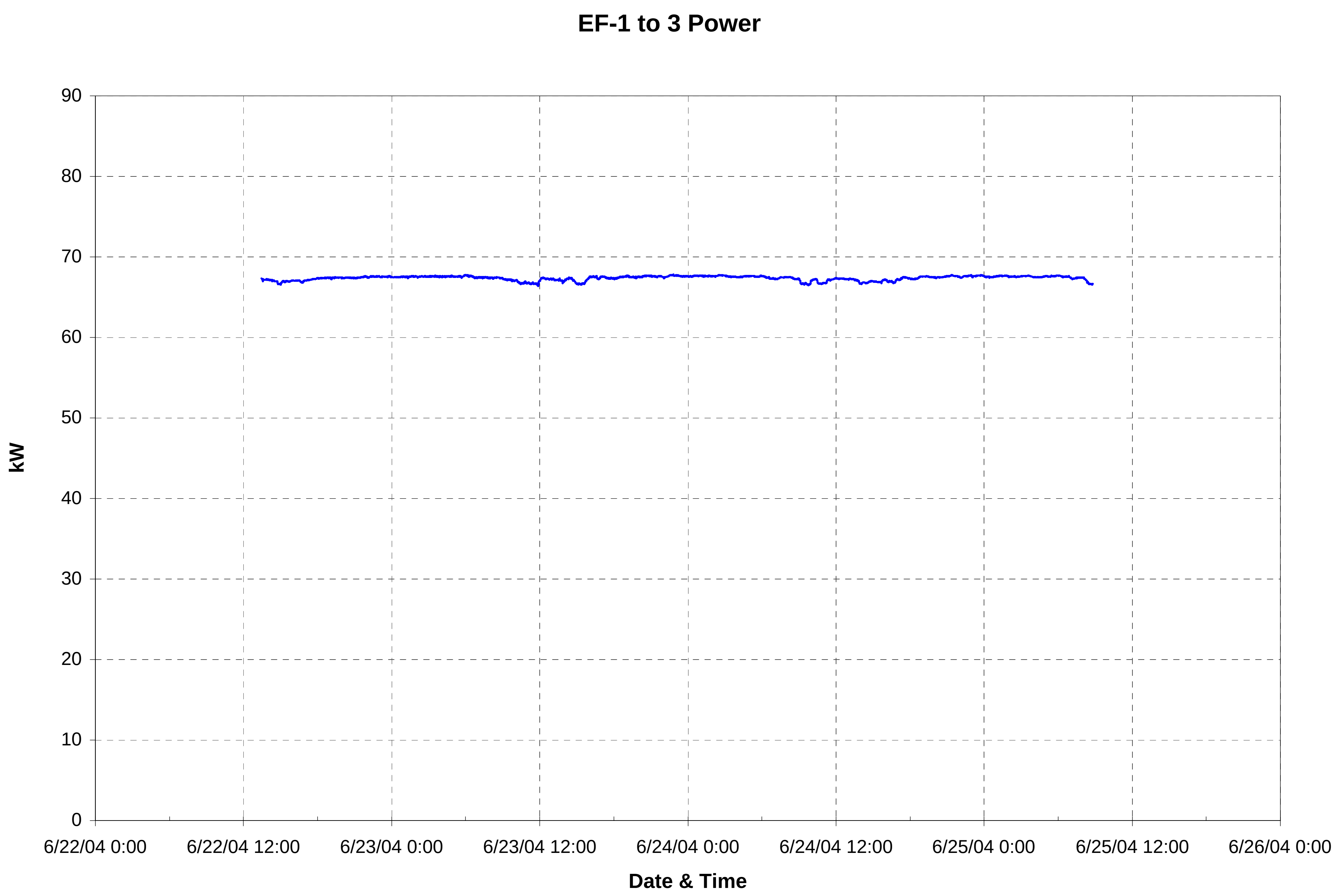
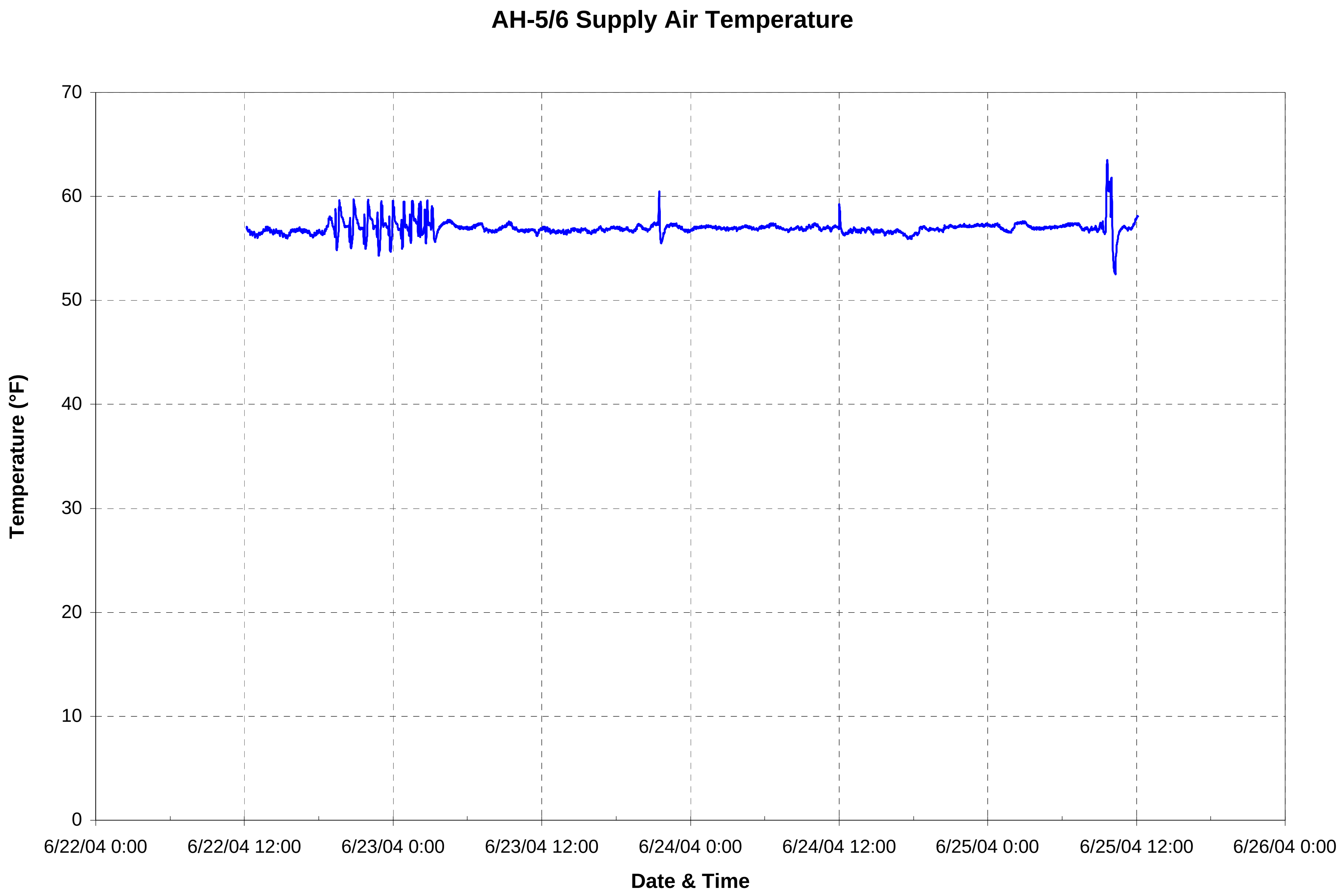
6/26/04 0:00
Date & Time


EF-1 to 3 Power
kW
0
10
20
30
40
50
60
70
80
90
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

“East Wing” Chemistry & Biology Laboratories


AH-5/6 Supply Air Temperature
Temperature (°F)
0
10
20
30
40
50
60
70
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
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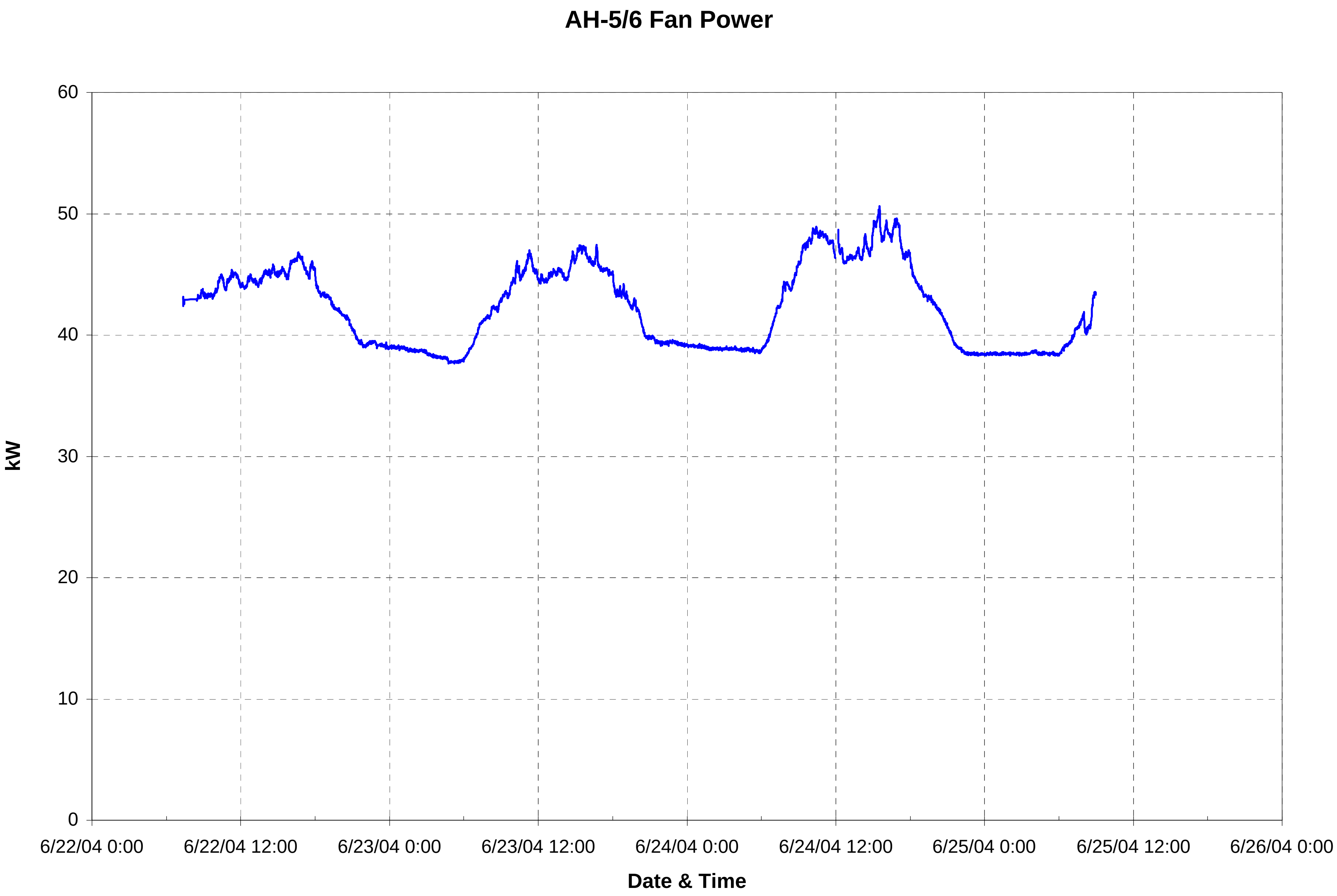
6/26/04 0:00
Date & Time


AH-5/6 Fan Power
kW
60
50
40
30
20
10
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
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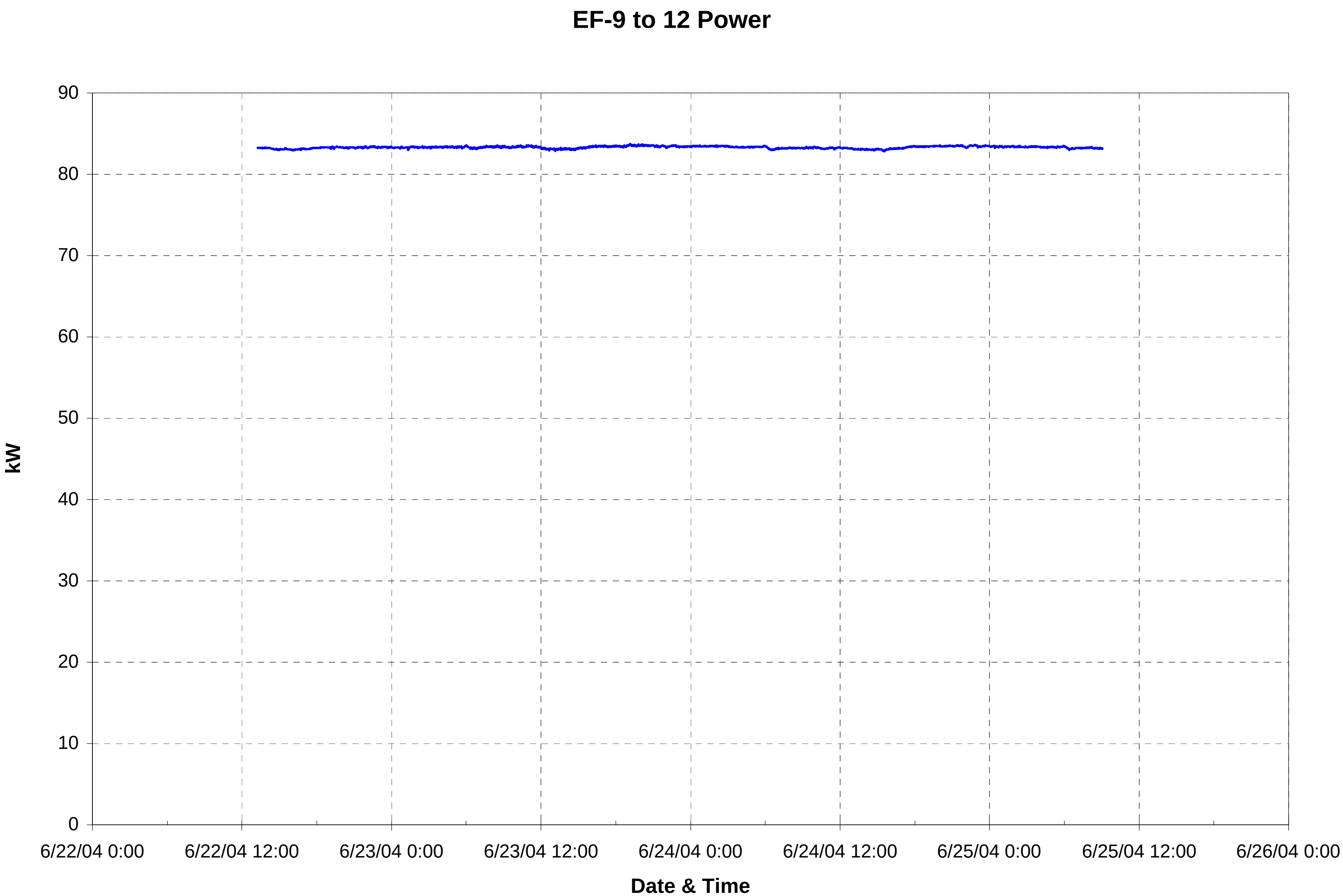
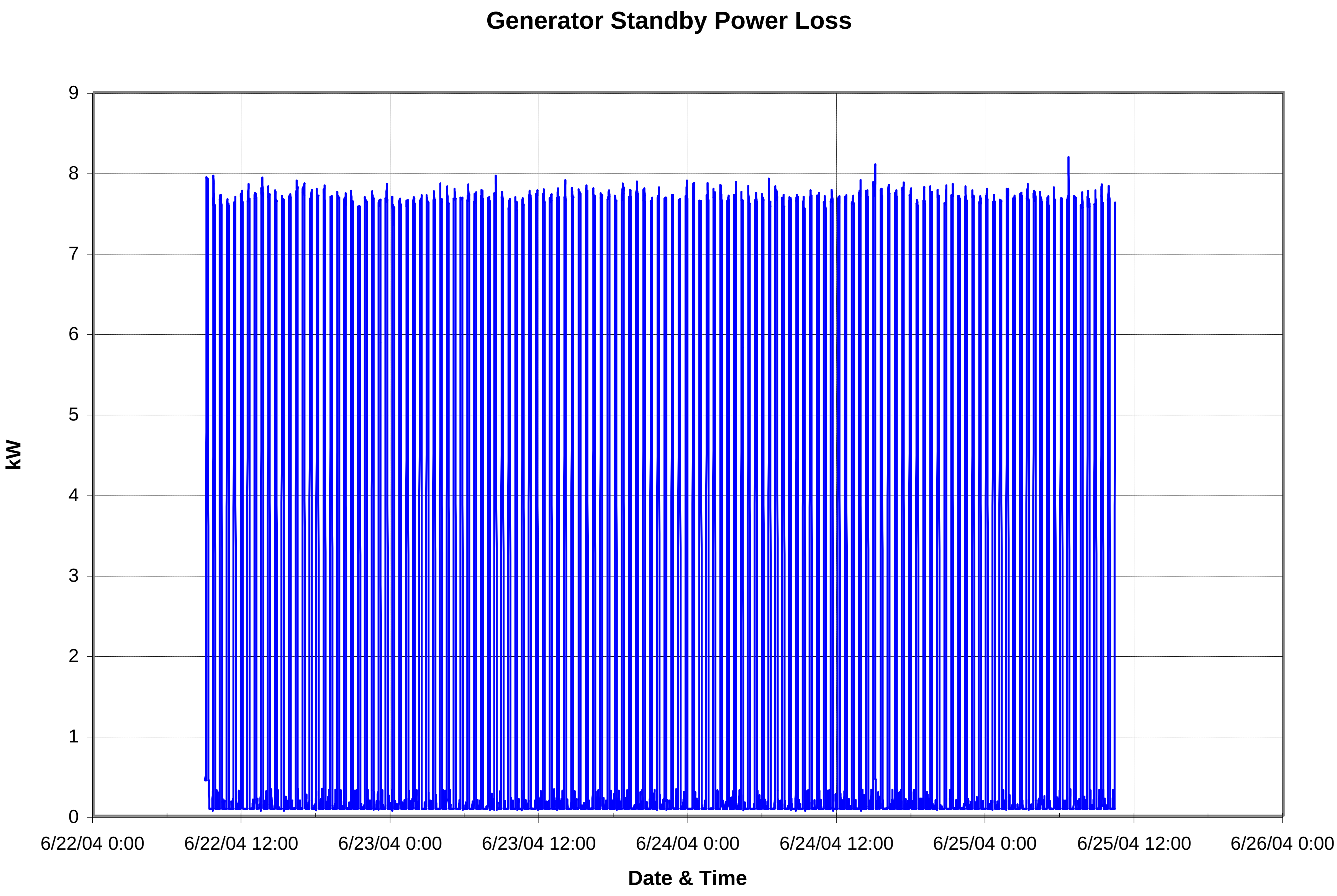
6/25/04 12:00
6/26/04 0:00
Date & Time


EF-9 to 12 Power
kW
90
80
70
60
50
40
30
20
10
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

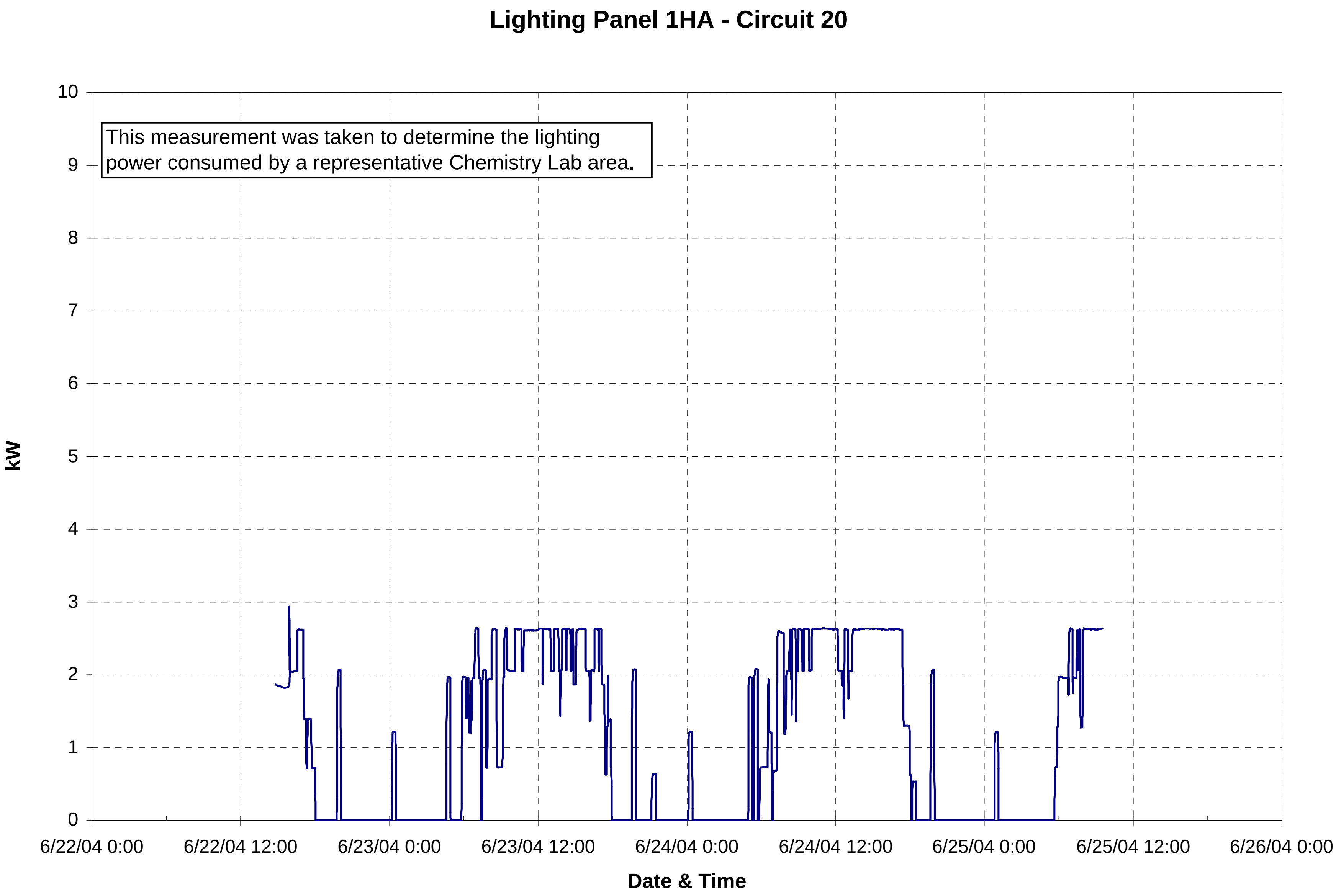
Electrical Systems

Backup Generator

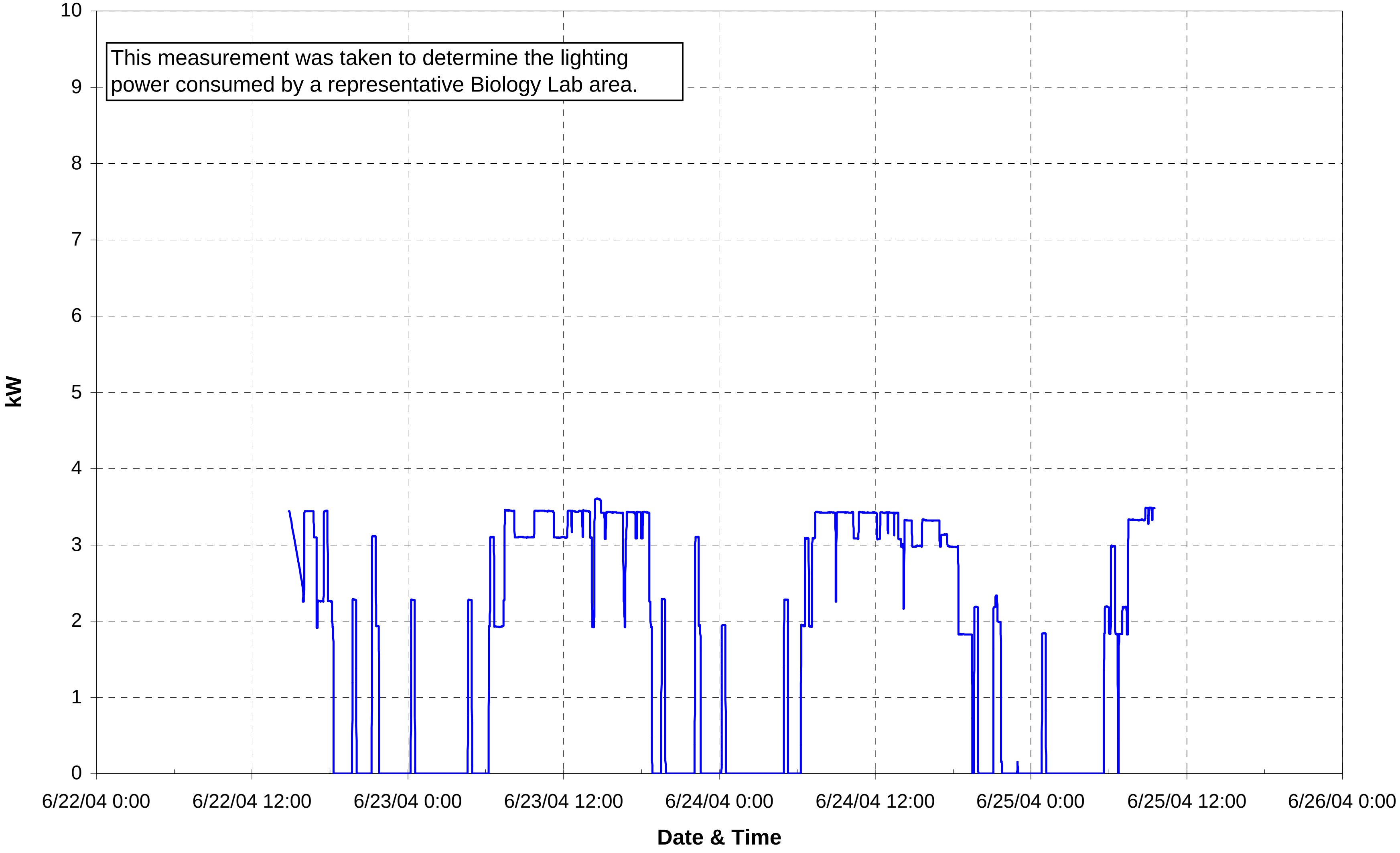


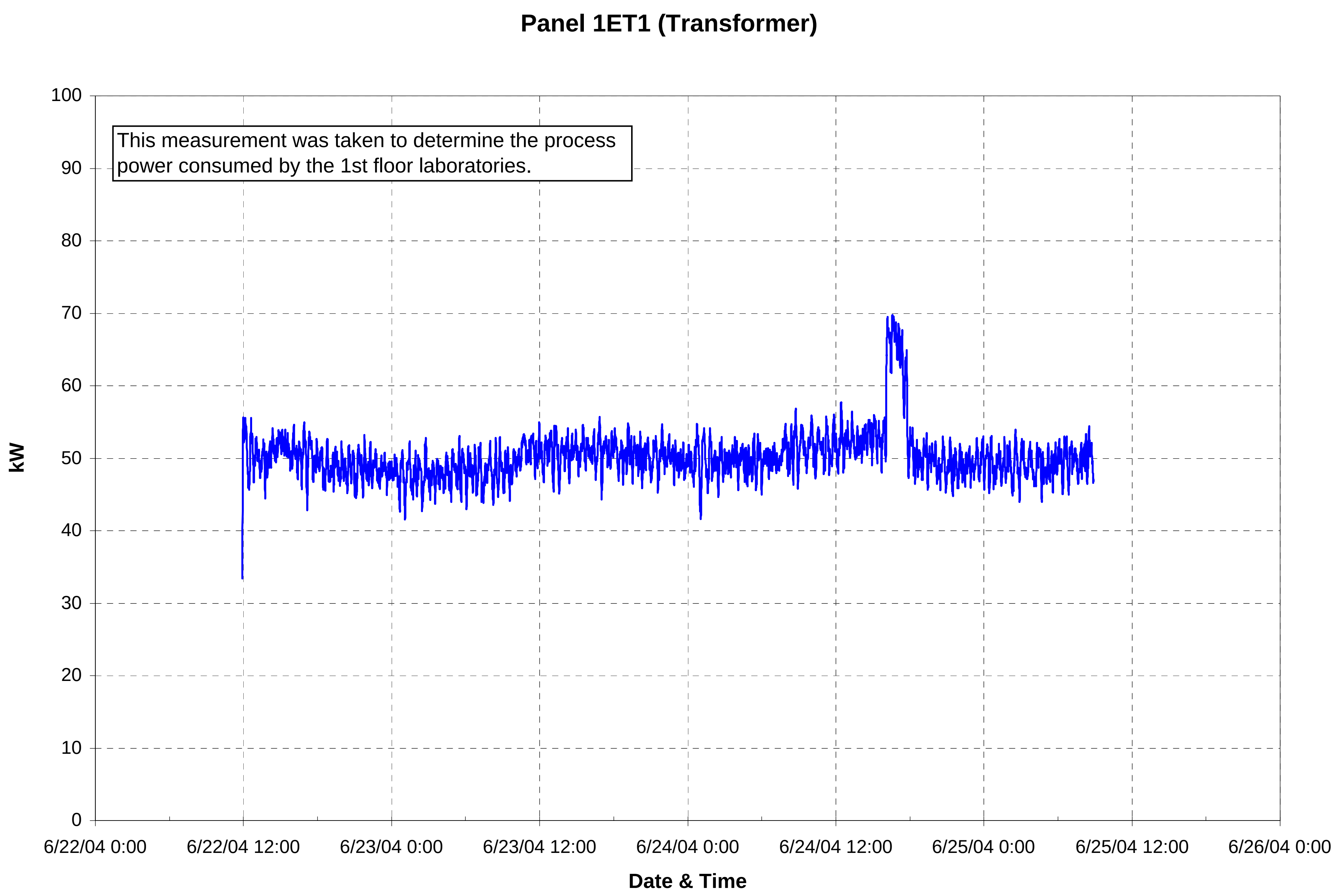
Generator Standby Power Loss
kW
0
1
2
3
4
5
6
7
8
9
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

Miscellaneous Electrical Measurements

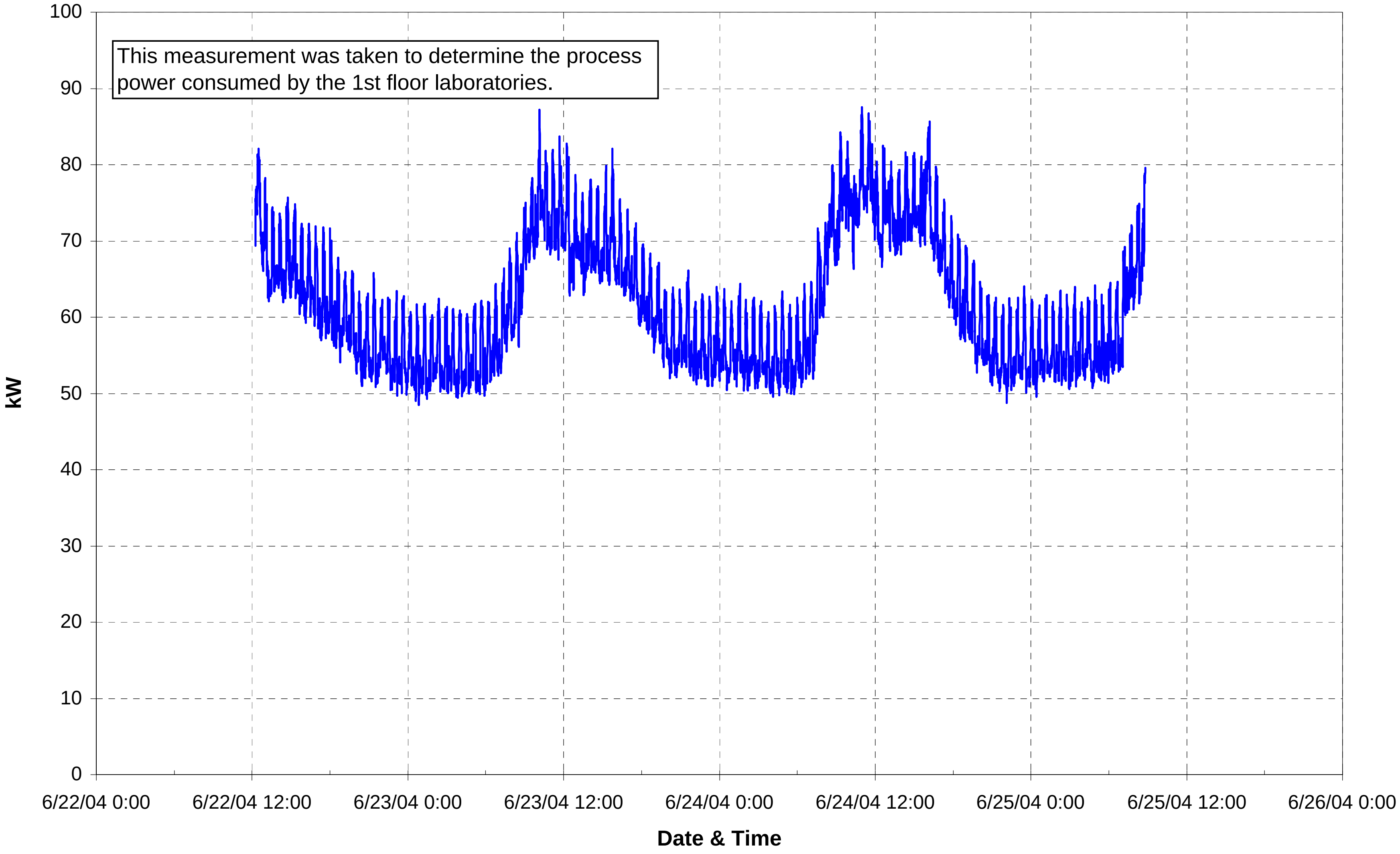

Lighting Panel 1HA - Circuit 20
This measurement was taken to determine the lighting power consumed by a representative Chemistry Lab area.
kW
10
9
8
7
6
5
4
3
2
1
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

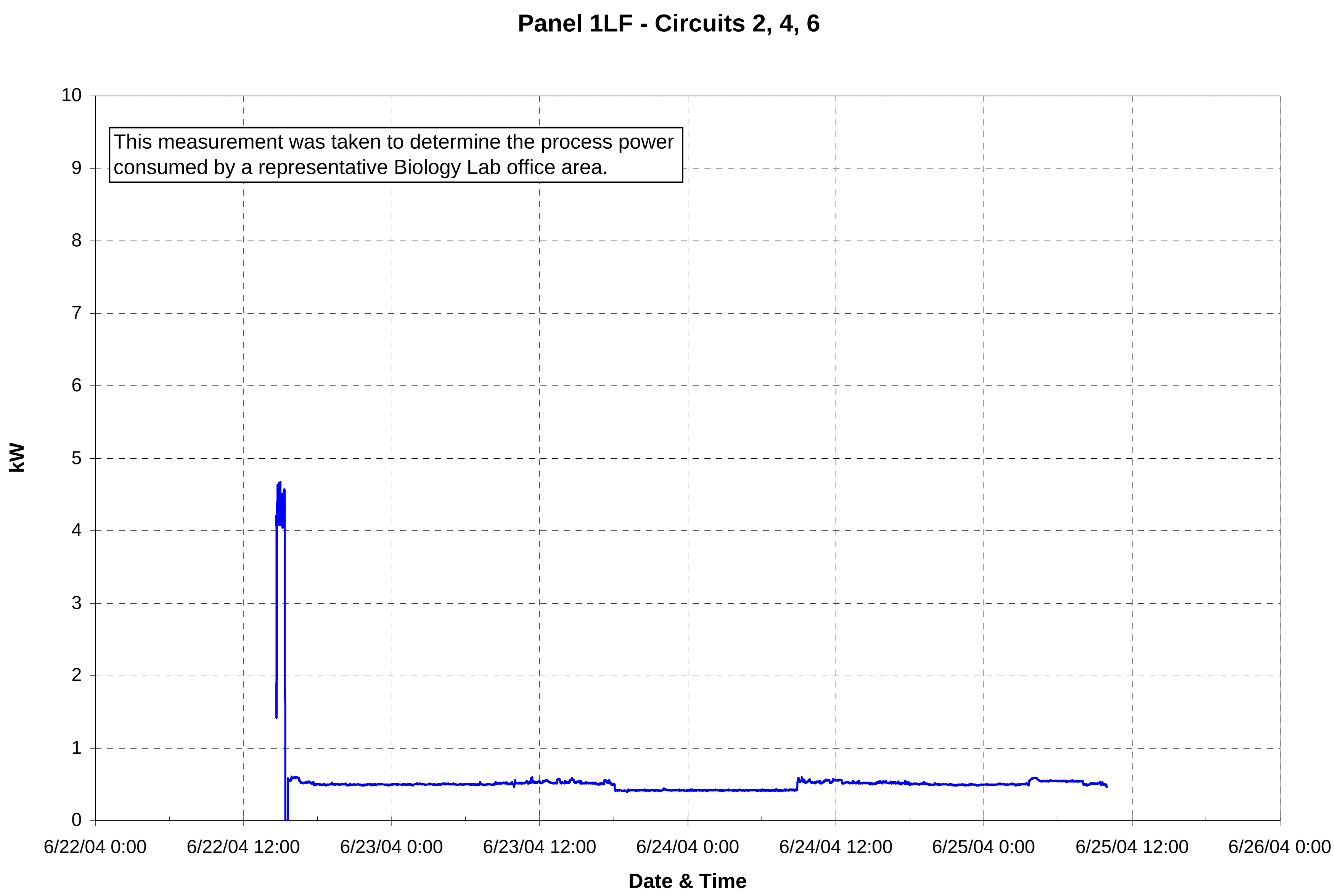
Lighting Panel 1HA - Circuits 23, 27

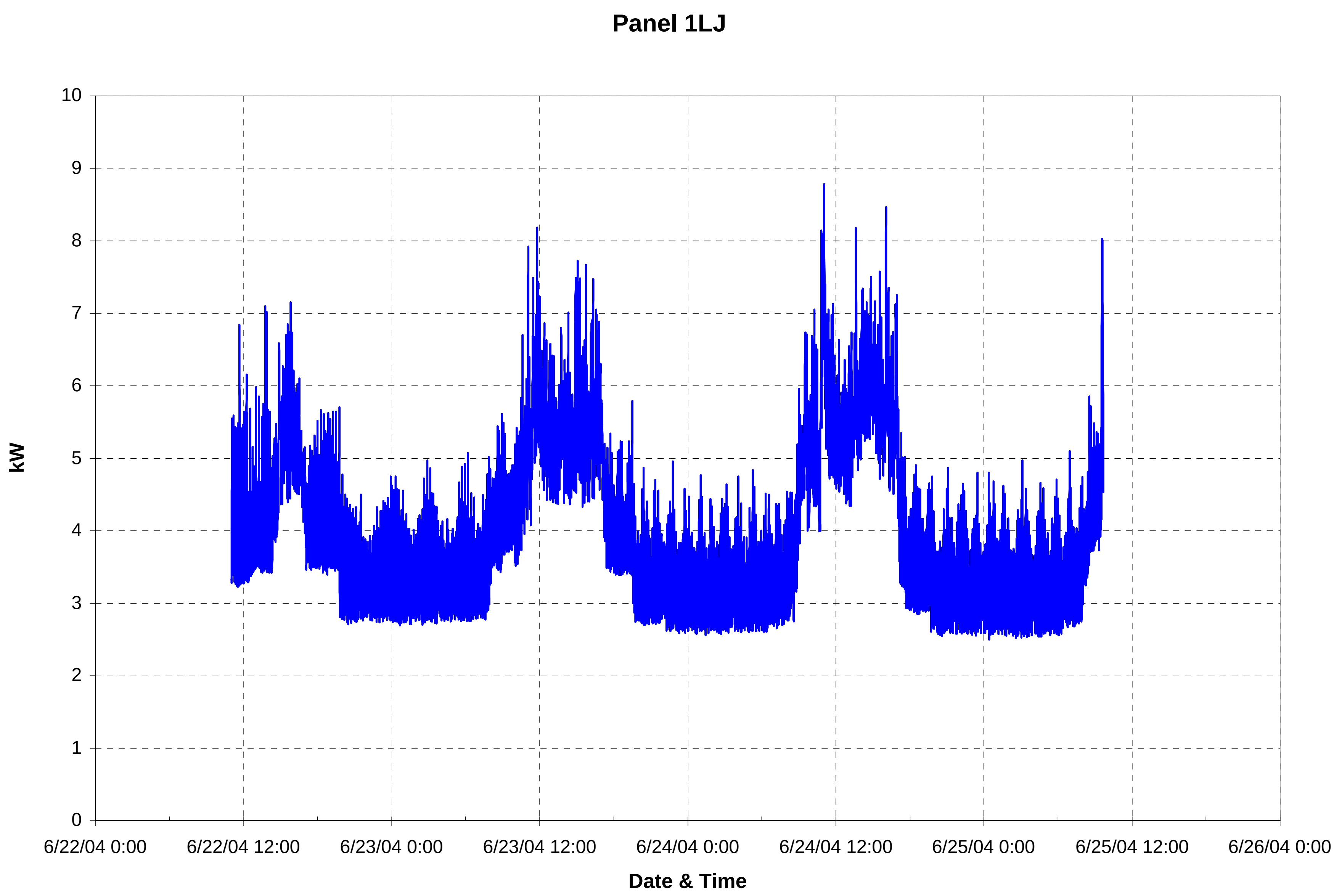


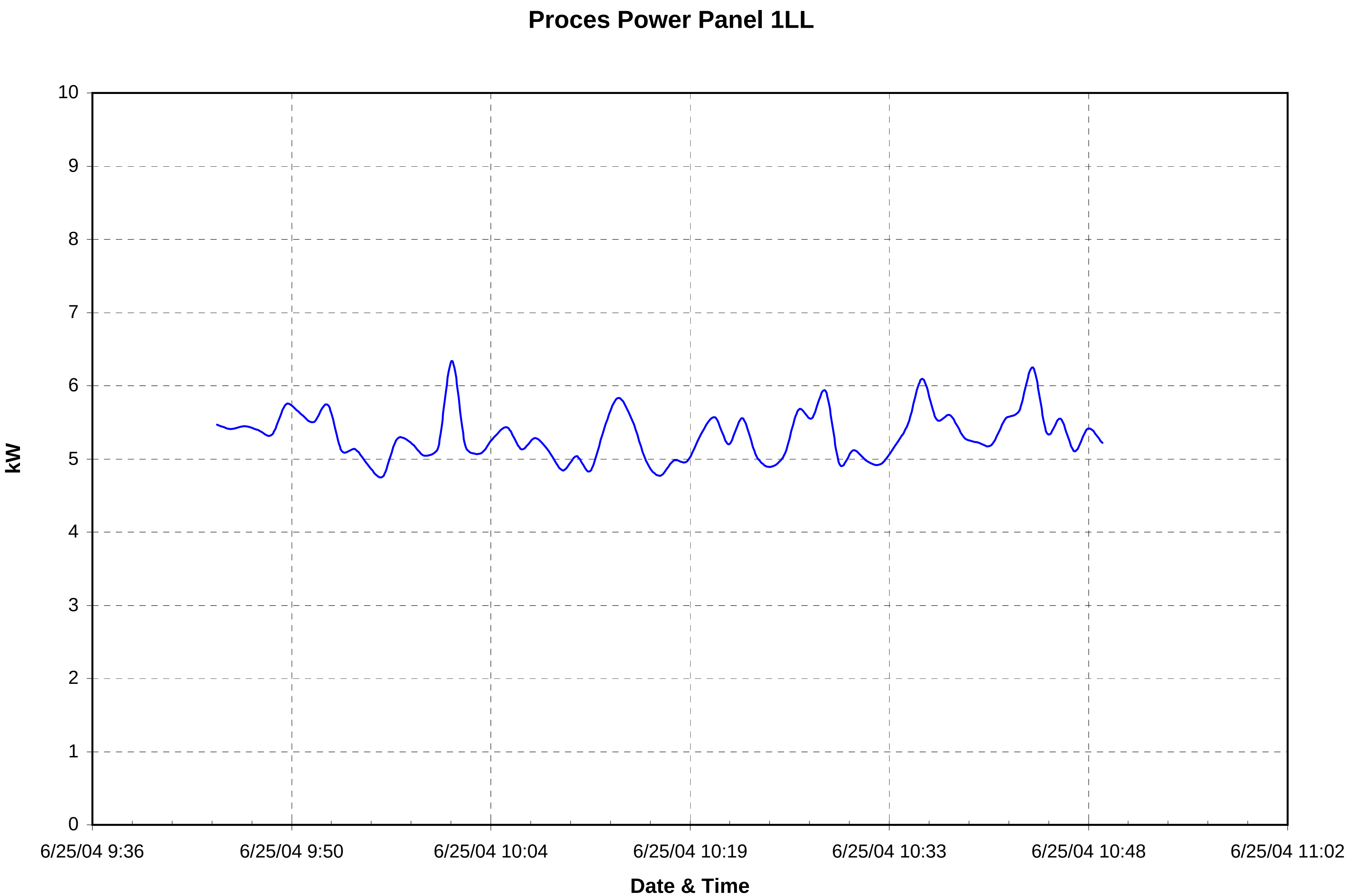

Panel 1ET1 (Transformer)
This measurement was taken to determine the process power consumed by the 1st floor laboratories.
kW
100
90
80
70
60
50
40
30
20
10
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

Panel 1T1 (Transformer)

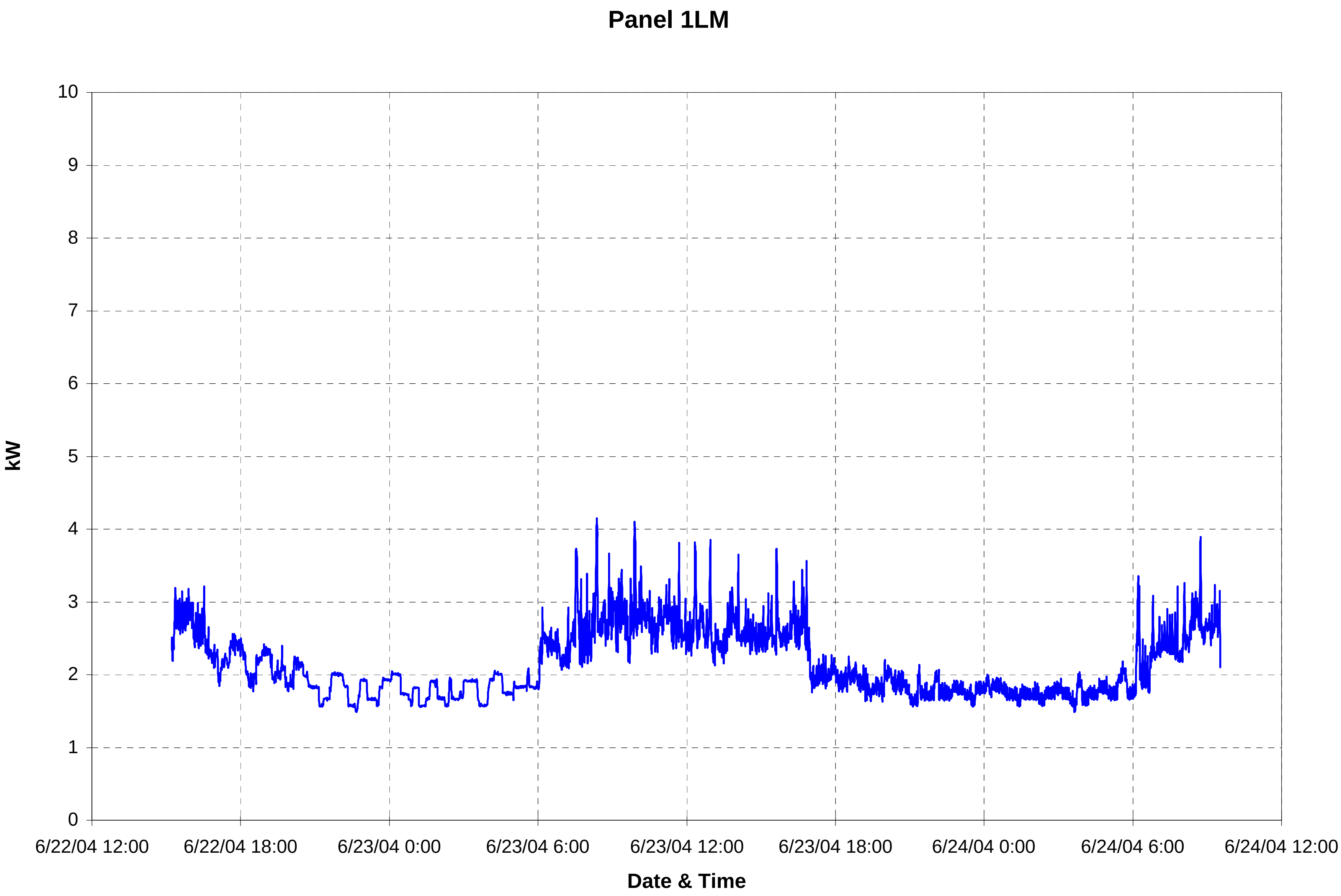



Panel 1LF - Circuits 2, 4, 6
This measurement was taken to determine the process power consumed by a representative Biology Lab office area.
kW
0
1
2
3
4
5
6
7
8
9
10
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

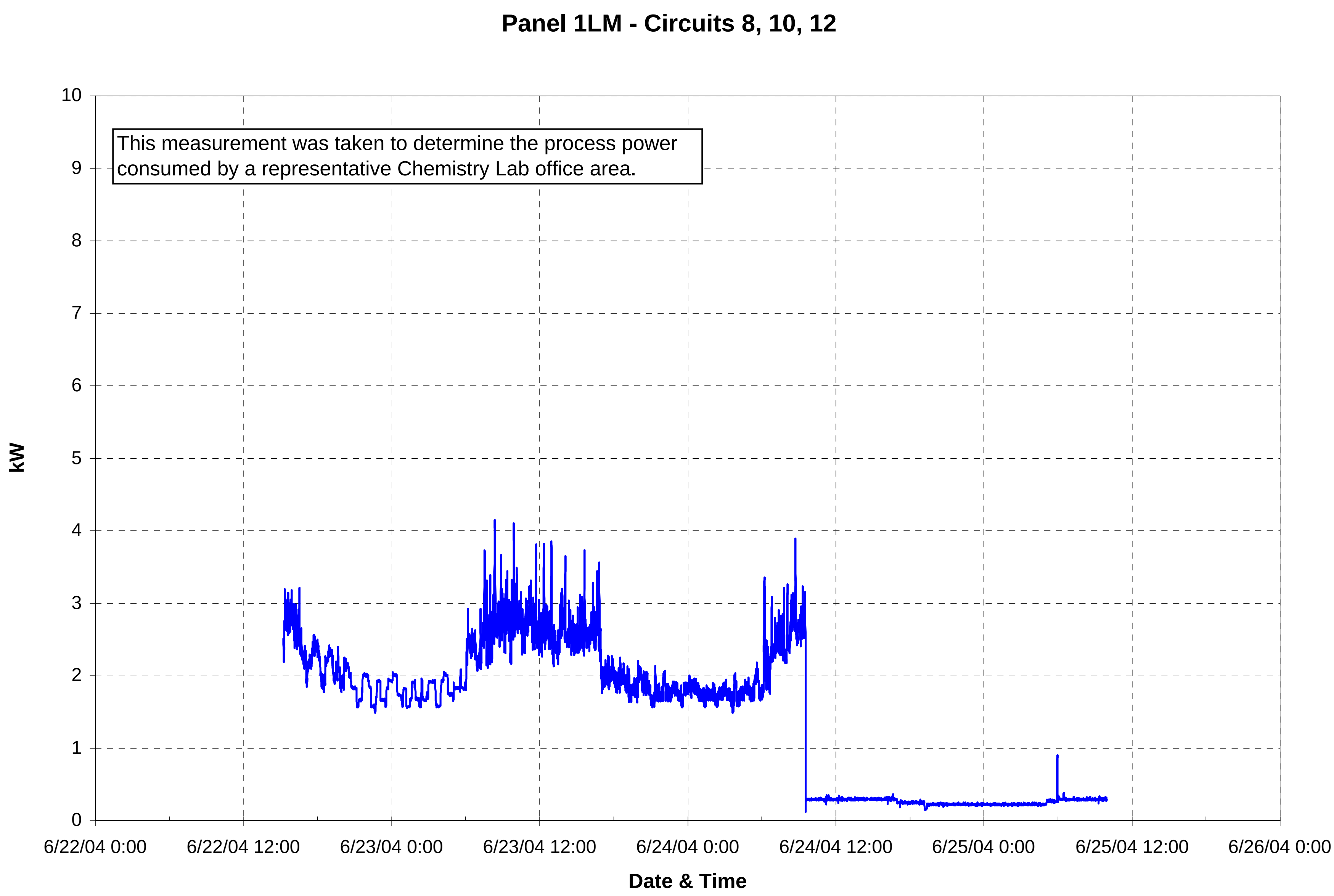

Panel 1LJ
kW
10
9
8
7
6
5
4
3
2
1
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

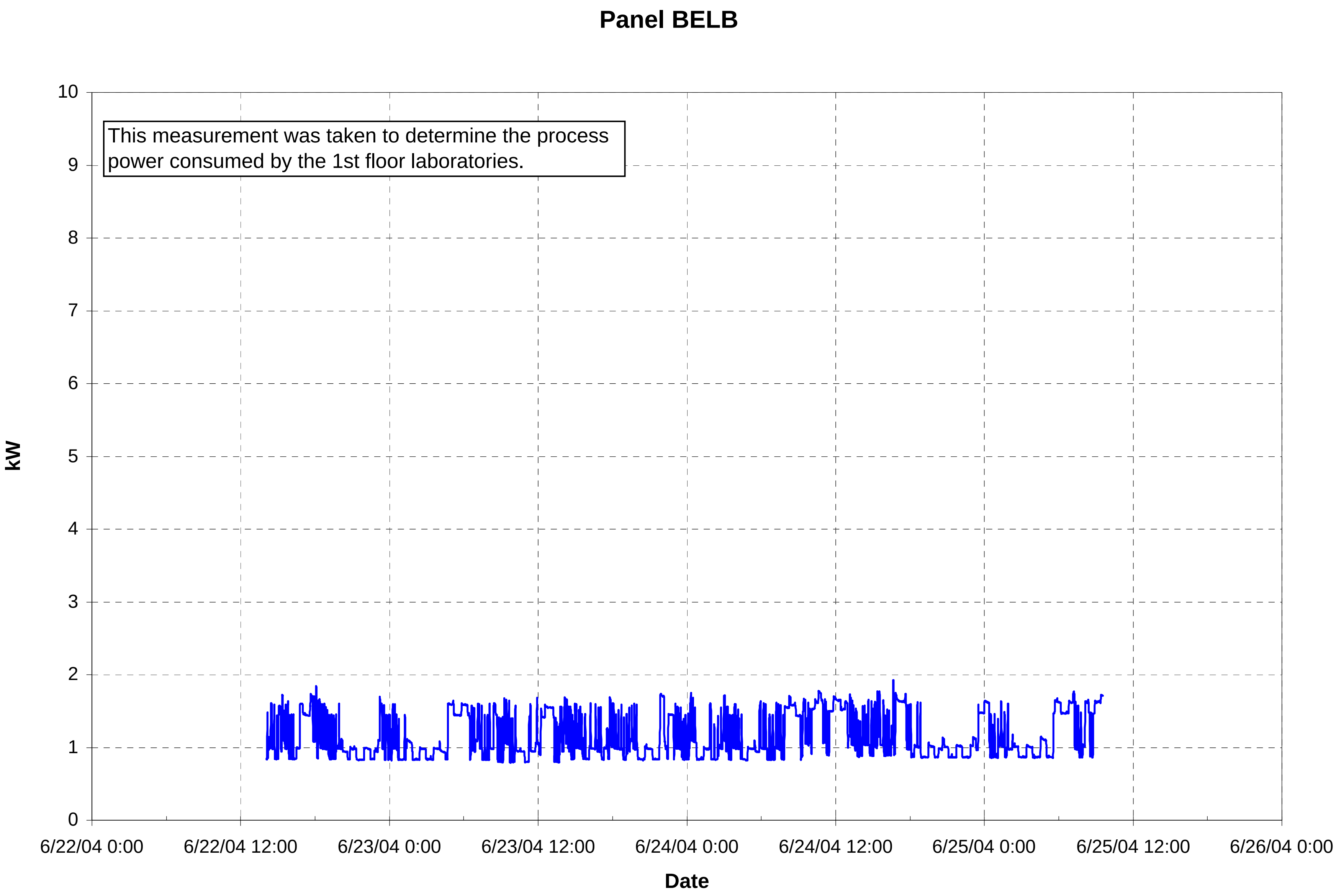


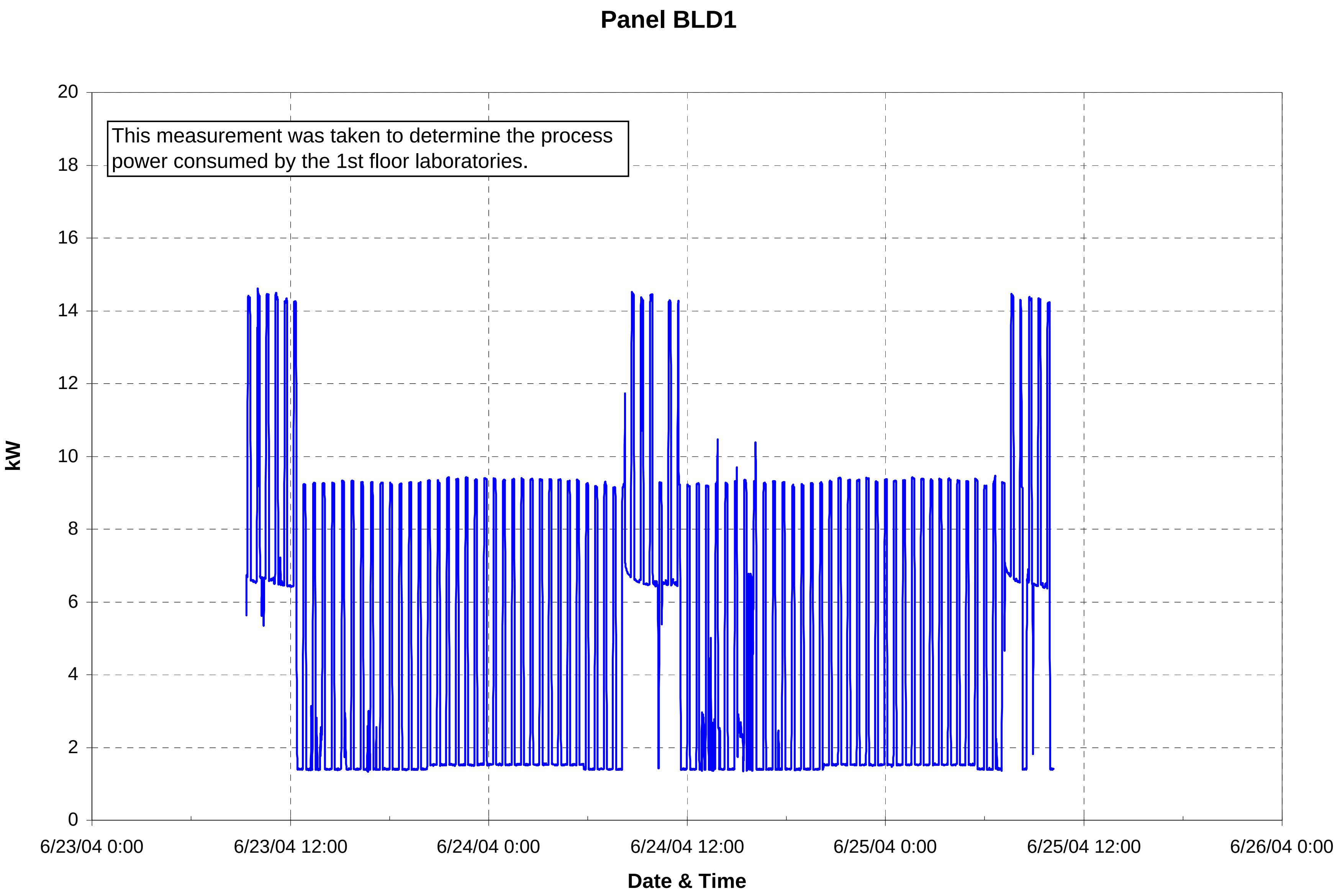
Proces Power Panel 1LL
kW
0
1
2
3
4
5
6
7
8
9
10
6/25/04 9:36
6/25/04 9:50
6/25/04 10:04
6/25/04 10:19
6/25/04 10:33
6/25/04 10:48
6/25/04 11:02
Date & Time



Panel 1LM
kW
10
9
8
7
6
5
4
3
2
1
0
6/22/04 12:00
6/22/04 18:00
6/23/04 0:00
6/23/04 6:00
6/23/04 12:00
6/23/04 18:00
6/24/04 0:00
6/24/04 6:00
6/24/04 12:00
Date & Time

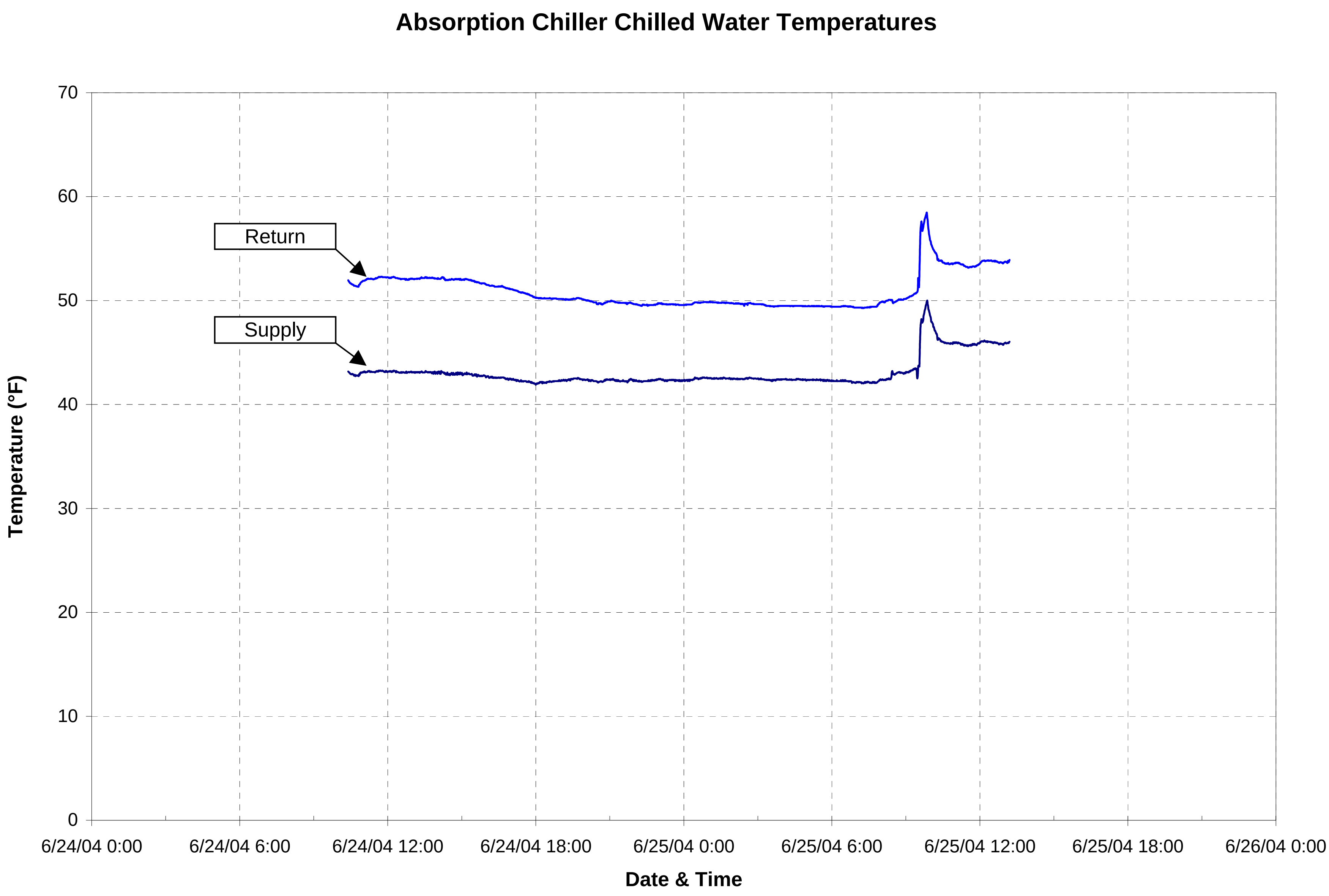

Panel 1LM - Circuits 8, 10, 12
This measurement was taken to determine the process power consumed by a representative Chemistry Lab office area.
kW
0
1
2
3
4
5
6
7
8
9
10
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time


Panel BELB
This measurement was taken to determine the process power consumed by the 1st floor laboratories.
kW
10
9
8
7
6
5
4
3
2
1
0
6/22/04 0:00
6/22/04 12:00
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date

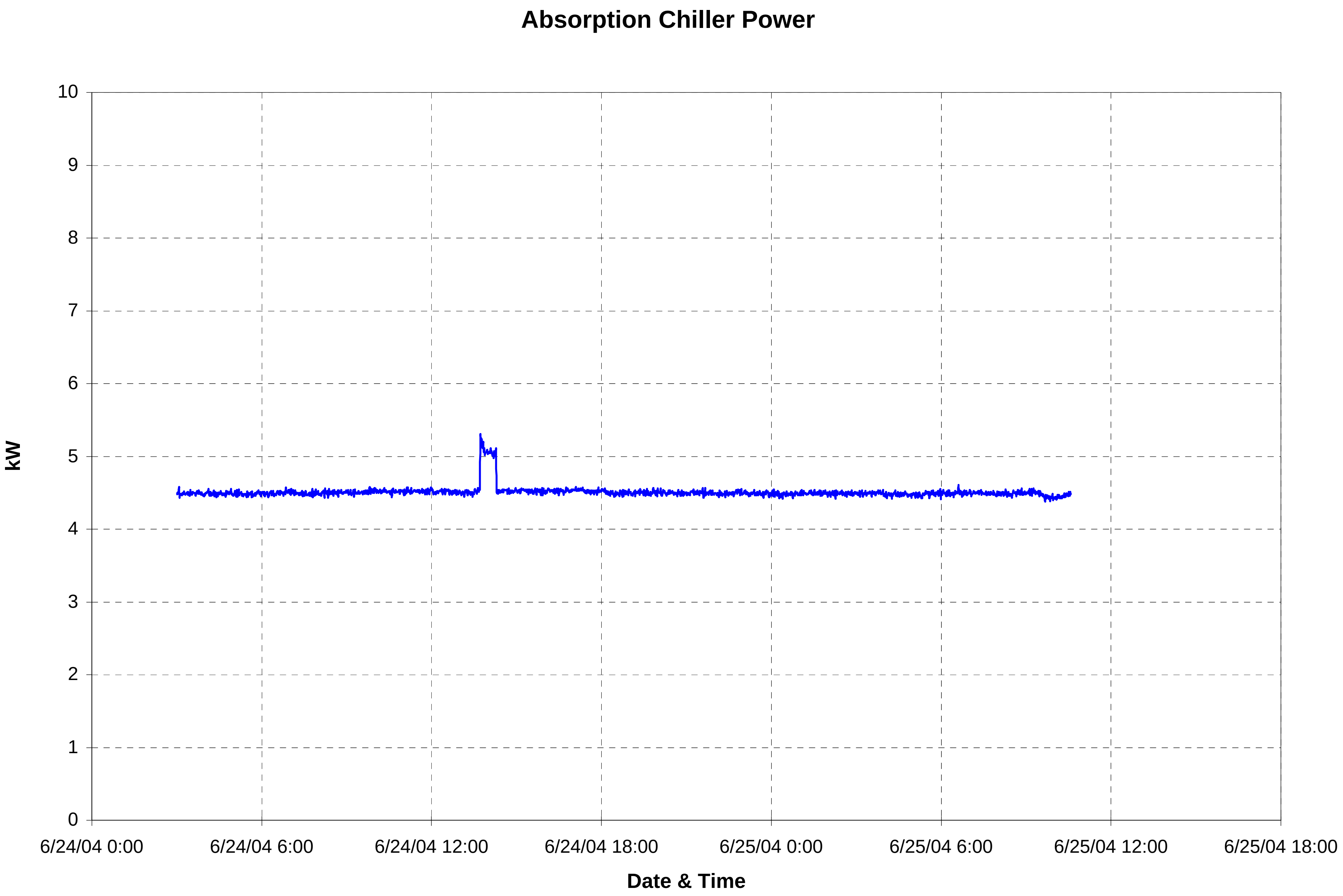


Panel BLD1
This measurement was taken to determine the process power consumed by the 1st floor laboratories.
kW
20
18
16
14
12
10
8
6
4
2
0
6/23/04 0:00
6/23/04 12:00
6/24/04 0:00
6/24/04 12:00
6/25/04 0:00
6/25/04 12:00
6/26/04 0:00
Date & Time

Absorption Chiller Measurements



Absorption Chiller Chilled Water Temperatures
Temperature (°F)
70
60
50
40
30
20
10
0
Return
Supply
6/24/04 0:00
6/24/04 6:00
6/24/04 12:00
6/24/04 18:00
6/25/04 0:00
6/25/04 6:00
6/25/04 12:00
6/25/04 18:00
6/26/04 0:00
Date & Time



Absorption Chiller Power
kW
10
9
8
7
6
5
4
3
2
1
0
6/24/04 0:00
6/24/04 6:00
6/24/04 12:00
6/24/04 18:00
6/25/04 0:00
6/25/04 6:00
6/25/04 12:00
6/25/04 18:00
Date & Time

Appendix B

Data Collection
and Accuracy Notes

Data Collection and Accuracy Notes

The following notes describe specific measurements and what assumptions were made in preparing calculated results.

Laboratory Data

Lighting Power	Lighting loads measured directly at their respective breakers for a representative laboratory area. The lighting power was then extrapolated based on the Watts/sf of the representative laboratory.
Process Power	Process tool loads measured directly at their respective breakers for a representative laboratory area. The process power was then extrapolated based on the Watts/sf of the representative laboratory.

Air Handler

Air Flow	All air flow measurements were provided by certification report.
Fan Power	Fan power was measured directly at the breaker.

Appendix C

Measurement Methodology

Measurement Methodology

Data collection measurements were made according to the following procedures:

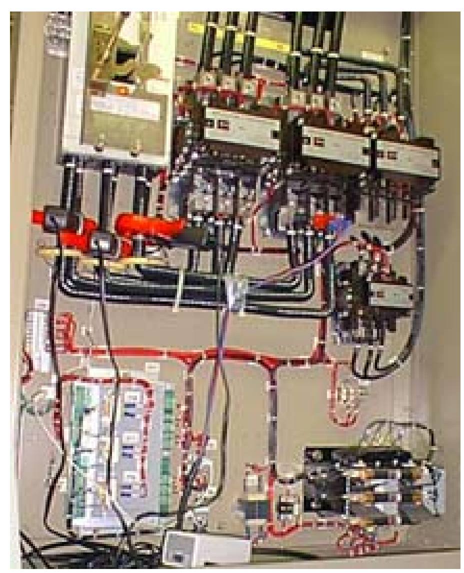
Water Temperature – Pete's Plug

- Equipment: Pace Scientific 4-channel pocket loggers model XR440, and 4" 30kOhm thermistors.
- Attach thermistor temperature sensor to pocket logger channel block.
- Setup pocket logger using product software.
- Verify channels set to correct sensor type and operation.
- Upload setup to pocket logger to launch logging.
- Insert thermistor into Pete's plug.
- Secure pocket logger to pipe.
- Read real time data. Verify setup and actual conditions.
- Log data.

Air Temperature/Relative Humidity – Air Handler

- Equipment: Pace Scientific 4-channel pocket loggers model XR440, 4" 30kOhm thermistors, or Temperature/Relative Humidity sensors.
- Attach temperature/relative humidity sensor to pocket logger channel block.
- Setup pocket logger using product software.
- Verify channels set to correct sensor type and operation.
- Set RH linear scale specified by the sensor.
- Upload setup into pocket logger to launch logging.
- Read real time data. Verify setup and actual conditions.
- Log data.

Power Trend – Elite Logger



- Equipment: Elite Logger and ELOG 97c software.
- Select current transducers (CTs) appropriate for the measurement and panel space constraints.
- Attach current transducers (CTs) to Elite logger channel block.
- Plug Elite logger into AC supply.
- Setup Elite logger using product software.
- Electrician installation of voltage sensors in the electrical panel.
- Electrician installation of CTs in electrical panel for the specified load to be measured.
- Read real time data.
- Verify balanced current as well as appropriate, balanced voltage readings.
- Secure panel door and attach caution tape and warning notice if panel cannot be locked shut.
- Log data.

Power Spot Measurement – Power Sight

- Equipment: Power Sight PS 3000
- Plug Power Sight into AC supply if necessary.
- Connect current transducers (CTs) and voltage sensors to Power Sight.
- Electrician installation of voltage sensors in the electrical panel.
- Electrician installation of CTs in electrical panel for the specified load to be measured.
- Verify balanced current as well as appropriate, balanced voltage readings.
- Read and record the real time power reading for spot measurement.
- Log data for selected measurements.